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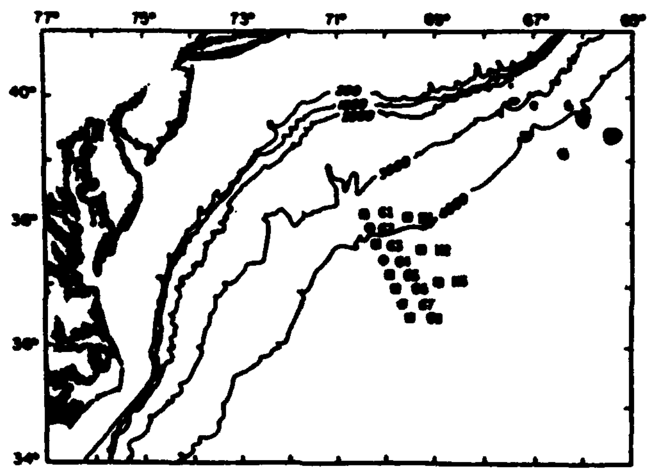
THE GULF STREAM DYNAMICS EXPERIMENT:

Inverted Echo Sounder Data Report for the May 1985 to June 1986 Deployment Period



by

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ABSTRACT

The continuation of the Gulf Stream Dynamics Experiment was conducted at 70°W, about 450 km northeast of Cape Hatteras, to study the baroclinic transport and cross-stream thermocline structure of the Gulf Stream. This report documents the inverted echo sounder data collected during the May 1985 to June 1986 deployment period. Time series plots of the half-hourly travel time and low-pass filtered thermocline depth measurements are presented for ten instruments. Bottom pressure and temperature, measured at three sites, are also plotted. Basic statistics are given for all the data records shown. Maps of the thermocline depth field in a 120 km by 260 km box region are presented at daily intervals.

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SECTION 1

Experiment Description and Data Processing

1.1 Introduction

This report documents data collected using inverted echo sounders (IESs) in the Gulf Stream northeast of Cape Hatteras from May 1985 to June 1986. These data are part of the Gulf Stream Dynamics Experiment conducted by the University of Rhode Island (D. R. Watts, PI) from July 1982 to June 1986. The measurements were made under the combined support of an NSF project entitled "The Dynamics of Gulf Stream Meanders" and an ONR project entitled "Observations on the Current Structure and Energetics of Gulf Stream Fluctuations Downstream of Cape Hatteras".

The principal objectives of the experiment were:

1) determining the baroclinic transport of the Gulf Stream along a section at 70°W where a local minimum in the meandering envelope has been observed,

2) determining the variability in the cross-stream structure of the Gulf Stream thermocline at this same location,

3) determining the Gulf Stream path and angle in the array area, and

4) selecting the station spacings so that they provide a variety of length scales for which we can calculate the correlation functions.

To address these objectives, an array of inverted echo sounders was deployed in the Gulf Stream approximately 450 km downstream of Cape Hatteras. The study area, shown in Figure 1, was occupied from May 1985 to June 1986. The IESs were located on two lines in an approximately

rectangular grid 130 km cross-stream by 70 km downstream. The instrument sites are shown in Figure 1 and listed in Table 1. Additionally, bottom pressure gauges with temperature sensors were included at three of the sites (indicated by the solid circles) along the western line. Deployment of the eleven IESs took place from 10 to 17 May 1985 on a cruise aboard the R/V ENDEAVOR (EN130). The instruments were recovered on a cruise aboard the USNS BARTLETT (BART1307).

1.2 Site and Record Naming Conventions

In this report, each instrument site and the associated data record are referred to by both a line letter and a site number. The two cross-stream lines are designated from west to east by the letters G and H. The IES sites along line G are numbered consecutively from 1 through 8, with site 1 located at the northwestern end of the line. Likewise, IES sites along line H are numbered from 1 through 3. The site designator has a prefix of either IES, indicating it is a standard inverted echo sounder (i.e., without any optional sensors), or PIES, if it is a combined IES and bottom pressure gauge. Additionally, a two-digit code, 86, indicates the year in which the instruments were recovered. For example, IES86G5, the fifth site from the northwestern end of line G, was recovered during 1986.

1.3 Inverted Echo Sounder Description

A detailed description of the IES is presented in Chaplin and Watts (1984) and will not be repeated here. Briefly, the IES is an instrument which is moored one meter above the ocean floor and which monitors the depth of the main thermocline acoustically. A sample burst

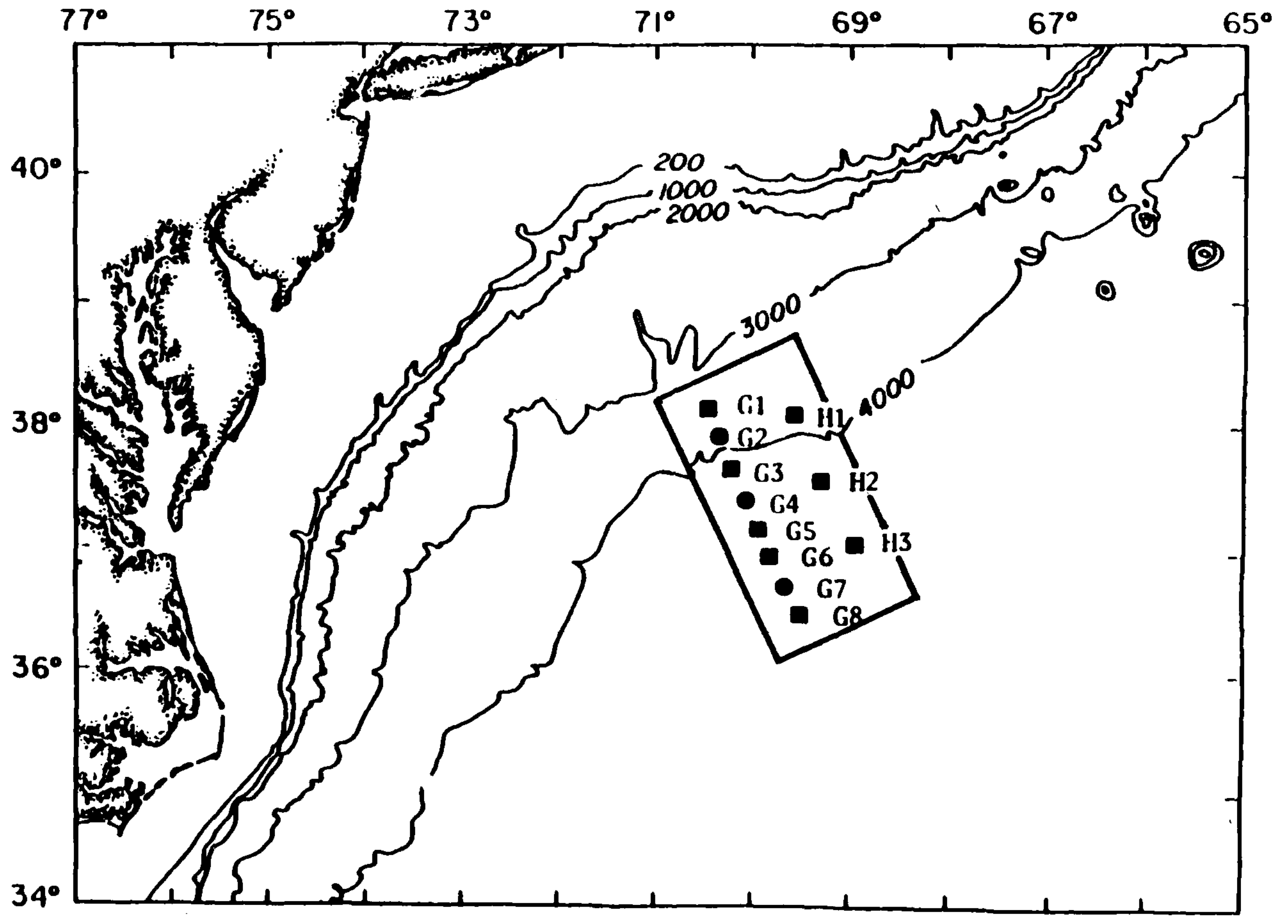


Figure 1. The Gulf Stream Dynamics Experiment Study Area. IES sites (solid squares and circles) along lines G and H were occupied in 1985-1986. IESs with bottom pressure gauges and temperature sensors were located at sites shown by the solid circles.

Table 1. Instrument Site Locations and Data Returns

SITE	LATITUDE (N)	LONGITUDE (W)	MJJASONDJFMAMJJ
IES86G1	38°09.01	70°26.06	XXXXXXXXXXXXXX
PIES86G2	37°53.94	70°18.02	XXXXXXXXXXXXXX
PIES86G3	37°39.38	70°09.48	
PIES86G4	37°23.95	70°01.08	XXXXXXXXXXXXXX
IES86G5	37°10.05	69°53.12	XXXXXXXXXXXXXX
IES86G6	36°56.00	69°45.21	XXXXXXXXXXXXXX
PIES86G7	36°40.97	69°36.99	XXXXXXXXXXXXXX
IES86G8	36°26.05	69°29.01	XXXXXXXXXXXXXX
IES86H1	38°06.15	69°33.78	XXXXXXX XXXXXX
IES86H2	37°34.09	69°17.08	XXXXXXXXXXXXXXX
IES86H3	37°01.97	68°59.91	XXXXXXXXXXXXXX

of acoustic pulses is transmitted every half hour and the round trip travel times to the surface and back are recorded on a digital cassette tape within the instrument. For the standard IES, a sample burst typically consists of twenty 10-kHz pings. Additionally, bottom pressure and temperature can be measured and recorded. During this deployment period, there were three instruments equipped with these optional sensors. For these three instruments, the travel time burst consists of 24 pings. Bottom pressure and temperature are not sampled in bursts, they are average measurements over the whole sampling period.

1.4 Data Processing

The raw data are recorded within the IES on Sea Data model 610 recorders. The cassette tape contains the counts associated with travel time measurements as a series of integer words of varying lengths. All processing was done on a PRIME 750 computer, except for the initial dumping of the data from the cassette tapes onto a 9-track magnetic tape. This was performed on the Hewlett Packard 2000 series computer maintained by the URI Marine Technicians. The basic processing steps, which include transcription, editing, and conversion into scientific units, are illustrated by the flowchart in Figure 2. The data processing is accomplished by a series of routines specifically developed for the IES (Tracey and Watts, 1987) and these are outlined below.

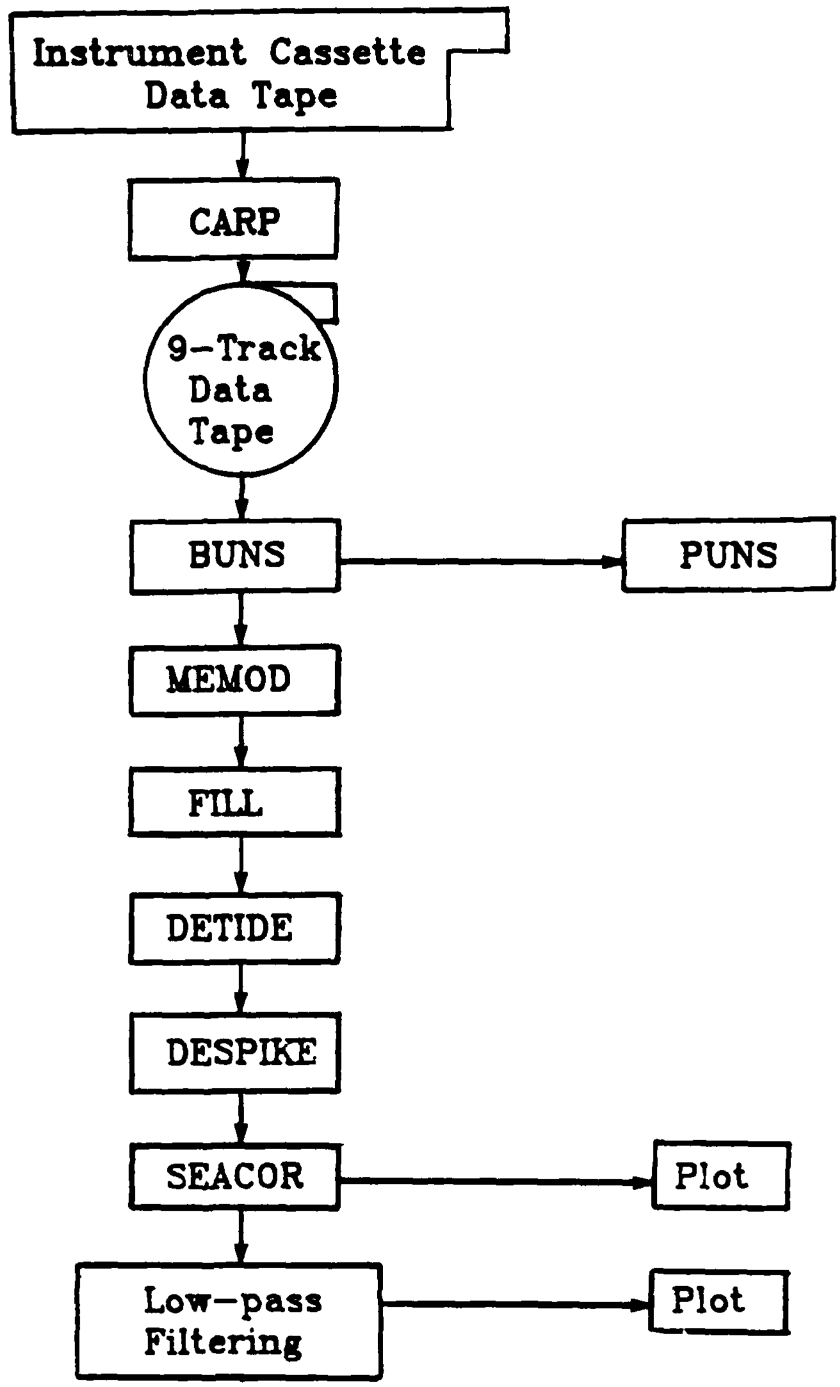


Figure 2. IES Data Processing Flowchart.

CARP: Transfers the data from cassettes to 9-track magnetic tape for subsequent processing.

BUNS: Converts the series of integer words of varying lengths into standard length 32-bit integer words.

PUNS: Produces integer listings and histograms of the travel time sample bursts. Provides an initial look at data quality and travel time distributions. Used to determine the first (after launch) and last (before recovery) 'on bottom' samples.

MEMOD: Establishes the time base. Determines either the median or modal value (at the user's option) of the travel time burst as the representative measurement. Converts all travel time counts into scientific units of seconds.

FILL: Checks for proper incrementing of the time base. Missing data points are filled by inserting interpolated values.

DETIDE: From user-supplied tidal constituents specific to each site, determines the tidal contribution to the travel times and removes it from the measured values.

DESPIKE: Identifies and replaces travel time spikes with interpolated values.

SEACOR: Removes the effects of seasonal warming and cooling of the surface layers from the travel times. Plots of the half-hourly travel times are generated.

LOW-PASS FILTERING: Convolves the travel times with a 40-hour low-pass Lanczos filter. The smoothed series are subsampled at six-hour intervals and plotted.

The FESTSA time series analysis package (Brooks, 1976), modified for the PRIME 750, was used to remove the higher frequency (tidal and inertial) motions from those with periods of several days or longer, which are the main focus of this project. The symmetric filter, with a Lanczos taper, was designed with the quarter-power point at 0.025 cph and the tidal cycle attenuated by 60 db. The half-hourly travel time data (plotted in Figures 3.1-10) were low-pass filtered and the smoothed output series (40 HRLP) have sampling intervals of six hours.

1.4.1 Travel Time Calibration

Variations in the travel times have been shown to be proportional to variations in the thermocline depth (Watts and Rossby, 1977; Watts and Wimbush, 1981). Calibration XBTs were taken at each IES site in order to convert the travel times (τ) into thermocline depths (ξ) according to the relation: $\xi = M\tau + B$, where M is a scale factor and the intercept B depends on the depth of the instrument. Regressions of τ versus ξ, performed for several instruments, show that the constant value, $M = -19.0$ m/sec, is appropriate for all these Gulf Stream sites. The values of B used for each instrument are listed in the tables in Section 2.

For practical purposes the main thermocline depth can be represented by the depth of an individual isotherm. For this work, we have chosen the 12°C isotherm since it is situated near the highest temperature gradient of the main thermocline and correlates well with τ (Rossby, 1969; Watts and Johns, 1982). The low-pass filtered travel time records were scaled to the thermocline depths (Z_{12}) and these records are shown in Figures 7.1-2. Since τ is resolved to 0.1 msec, the 40 HRLP Z_{12} scaled values are therefore resolved to ± 2 m. However, there is a constant offset of ± 25 m for most records, which is the estimated accuracy of the intercept B. This is determined from the several calibration XBTs taken at each site.

1.4.2 Bottom Pressure

Digiquartz pressure sensors (models 46K-032, 75K-002, and 76KB-032) manufactured by Paroscientific, Inc. were used to measure bottom pressure. All pressure measurements were corrected for the temperature

sensitivity of the transducer, using calibration coefficients purchased from the manufacturer. The half-hourly measured bottom pressures (Figures 4.1-3) are dominated by the tides, however the pressures also drift, O(0.4 dbar), monotonically with time. Processing of the pressure measurements includes removing the long-term drift and the tides as follows.

Tidal response analysis (Munk and Cartwright, 1977) was used to determine the tidal constituents for each instrument. The calculated tides were then removed from the pressure records. The amplitudes, H (dbar), and phases, G° (Greenwich epoch), of the constituents are given in the tables in Section 2.

In order to estimate and remove the long-term drift from the measurements, we least-squares fit either an exponential or an exponential-linear function to our data (Watts and Kontoyiannis, 1986). The functional form was:

$$DRIFT = P_1[1 - \exp(P_2 t)] + P_4 t + P_3$$

where t is the time, and P_1, P_2, P_3, and P_4 are free paramemters. For the exponential function, P_4, is zero. The time origin (when the drift started) was assumed to be one hour before the first bottom sample. We also removed the first 12 hours of data after the instrument had reached the seafloor since the sensors were still coming into thermal equilibrium. Thus, t = 13 hours is the time associated with the first data point used. The parameters P_1, P_2, P_3, and P_4 were determined for each instrument using the non-linear regression subroutine P3R of BMDP-79, a package of computer programs developed at the Health Science Computing Facility, UCLA (Dixon and Brown, 1979). These coefficients

are listed in Section 2 for each record.

The half-hourly pressures are resolvedto 0.001 dbar, and the mean pressure is accurate to within 1.5 dbar. Watts and Kontoyiannis (1986) estimate that the residual (drift and tide removed) bottom pressure records (Figures 5.1-3) have an accuracy (relative to their mean pressures) of at least 0.05 dbar. The residual bottom pressure records were low-pass filtered as mentioned above, and are shown in Figure 8.

1.4.3 Temperature

Temperatures (Figures 6.1-3) were measured using Sea Data DC-37B electronics and a Yellow Springs International Corporation thermistor (model 44032), in order to correct the pressure values for the temperature sensitivity of the transducer. The thermistor is inside the instrument, on the pressure tranducer, rather than in the water. However, once the temperature probe has reached equilibruim with the surrounding waters, it also provides accurate measurements of the bottom temperature fluctuations (effectively low-pass filtered with a 4 hour e-folding equilibruim time). The first 24 half-hourly points were dropped prior to low-pass filtering, since the temperatures took 12 hours to reach equilibrium within 0.001°C. The accuracy of the temperature measurements is about 0.1°C, and the resolution is 0.0002°C. The temperature records were low-passed filtered and are shown in Figure 9.

1.4.4 Time Base

The date and time were assigned to each sampling period. The tables in Section 2 report the hour, minutes, and seconds associated with the first and last sampling period as a six-digit number. All

times are given as Greenwich Mean Time (GMT). For processing convenience, the times were converted into yearhours. Table 2 lists the yearhour which corresponds to 0000 GMT of each day for non-leap years. (For leap years, the yearhours can be determined by adding 24 to each day after February 28). There are a total of 8760 hours in a standard (non-leap) year and 8784 hours in a leap year. The yearhours given in this report are referenced to 0000 GMT on January 1, 1986, with measurements occurring between January and June 1986 assigned positive yearhours. Negative values correspond to sampling periods occurring during May through December 1985.

1.4.5 Special Processing of IES86H1

The instrument at site IES86H1 experienced tape recorder difficulties during the second half of the deployment period. These problems affected the quality of both the travel time measurements and the time base. We were successful in recovering all but two months of these data.

The tape difficulties began in mid-November 1985 and continued until the instrument was recovered in June 1986. For the period 24 November 1985 to 27 January 1986, the recorded signals were so poor that we were unable to recover any of the data. The quality of the recording steadily improved throughout the remainder of the deployment, but never regained the normal level. The data collected from May 1985 through mid-November were not affected by the tape problems.

Adaptations were made to the BUNS program in order to perform bit manipulations on the τ measurements. The standard deviations of the resulting τ's were about 3 msec, about three times greater than those

normally found (Chaplin and Watts, 1984). The subsequent processing steps remained the same, except that the τ's were despiked prior to filling the record gaps.

Special processing programs were developed to recover the sequence numbers, which are used to determine the time base. Since the quality of one of the four tracks on the cassette tape was considerably better than the others, we were able to accurately (within ±1 record) reestablish time base every 32 hours. Since the sampling interval was 30 minutes, there should have been 64 records within each of these intervals. Typically, however, this was not the case. Since we were unable to determine the timing at smaller increments, we forced these records to be evenly spaced throughout each 32-hour interval. For the time period from the end of November through mid-February, only 30% of the records were recovered from the tape; thus the actual time associated with each record may be in error by about 3 hours. By the end of April, when the recovery rate was about 85%, the error is reduced to 1/2 hour every three hours. These timing errors have very little effect on the 40HRLP filtered data; the accuracy of the time base associated with the Z_{12} data should be equivalent to those of other instruments.

1.5 Data Recovery

Table 1 summarizes the data returns from each of the inverted echo sounders. Of the eleven instruments deployed, all but one, PIES86G3, were recovered, giving an instrument recovery rate of 91%. The travel time detectors on the recovered instruments performed successfully; however the tape recorder in one IES (IES86H1) malfunctioned. Special

processing steps were required in order to obtain the travel time data for this instrument; these efforts were successful in that all but two months of the data were recovered. Overall, the data return rate for the travel time measurements was 98%. Complete records were obtained for the three bottom pressure gauges and temperature sensors; thus the return rate was 100% for these data.

TABLE 2. Yearhour calendar for non-leap years. Only the yearhour corresponding to 0000 GMT is listed for each day.

JAN DATE	JAN YEAR DAY	JAN HOUR (0000Z)	FEB DATE	FEB YEAR DAY	FEB HOUR (0000Z)	MAR DATE	MAR YEAR DAY	MAR HOUR (0000Z)	APR DATE	APR YEAR DAY	APR HOUR (0000Z)	MAY DATE	MAY YEAR DAY	MAY HOUR (0000Z)	JUNE DATE	JUNE YEAR DAY	JUNE HOUR (0000Z)
1	1	0	1	32	744	1	60	1416	1	91	2160	1	121	2880	1	152	3624
2	2	24	2	33	768	2	61	1440	2	92	2184	2	122	2904	2	153	3648
3	3	48	3	34	792	3	62	1464	3	93	2208	3	123	2928	3	154	3672
4	4	72	4	35	816	4	63	1488	4	94	2232	4	124	2952	4	155	3696
5	5	96	5	36	840	5	64	1512	5	95	2256	5	125	2976	5	156	3720
6	6	120	6	37	864	6	65	1536	6	96	2280	6	126	3000	6	157	3744
7	7	144	7	38	888	7	66	1560	7	97	2304	7	127	3024	7	158	3768
8	8	168	8	39	912	8	67	1584	8	98	2328	8	128	3048	8	159	3792
9	9	192	9	40	936	9	68	1608	9	99	2352	9	129	3072	9	160	3816
10	10	216	10	41	960	10	69	1632	10	100	2376	10	130	3096	10	161	3840
11	11	240	11	42	984	11	70	1656	11	101	2400	11	131	3120	11	162	3864
12	12	264	12	43	1008	12	71	1680	12	102	2424	12	132	3144	12	163	3888
13	13	288	13	44	1032	13	72	1704	13	103	2448	13	133	3168	13	164	3912
14	14	312	14	45	1056	14	73	1728	14	104	2472	14	134	3192	14	165	3936
15	15	336	15	46	1080	15	74	1752	15	105	2496	15	135	3216	15	166	3960
16	16	360	16	47	1104	16	75	1776	16	106	2520	16	136	3240	16	167	3984
17	17	384	17	48	1128	17	76	1800	17	107	2544	17	137	3264	17	168	4008
18	18	408	18	49	1152	18	77	1824	18	108	2568	18	138	3288	18	169	4032
19	19	432	19	50	1176	19	78	1848	19	109	2592	19	139	3312	19	170	4056
20	20	456	20	51	1200	20	79	1872	20	110	2616	20	140	3336	20	171	4080
21	21	480	21	52	1224	21	80	1896	21	111	2640	21	141	3360	21	172	4104
22	22	504	22	53	1248	22	81	1920	22	112	2664	22	142	3384	22	173	4128
23	23	528	23	54	1272	23	82	1944	23	113	2688	23	143	3408	23	174	4152
24	24	552	24	55	1296	24	83	1968	24	114	2712	24	144	3432	24	175	4176
25	25	576	25	56	1320	25	84	1992	25	115	2736	25	145	3456	25	176	4200
26	26	600	26	57	1344	26	95	2016	26	116	2760	26	146	3480	26	177	4224
27	27	624	27	58	1368	27	86	2040	27	117	2784	27	147	3504	27	178	4248
28	28	648	28	59	1392	28	87	2064	28	118	2808	28	148	3528	28	179	4272
29	29	672				29	88	2088	29	119	2832	29	149	3552	29	180	4296
30	30	696				30	89	2112	30	120	2856	30	150	3576	30	181	4320
31	31	720				31	90	2136				31	151	3600			

JULY DATE	JULY YEAR DAY	JULY HOUR (0000Z)	AUG DATE	AUG YEAR DAY	AUG HOUR (0000Z)	SEPT DATE	SEPT YEAR DAY	SEPT HOUR (0000Z)	OCT DATE	OCT YEAR DAY	OCT HOUR (0000Z)	NOV DATE	NOV YEAR DAY	NOV HOUR (0000Z)	DEC DATE	DEC YEAR DAY	DEC HOUR (0000Z)
1	182	4344	1	213	5088	1	244	5832	1	274	6552	1	305	7296	1	335	8016
2	183	4368	2	214	5112	2	245	5856	2	275	6576	2	306	7320	2	336	8040
3	184	4392	3	215	5136	3	246	5880	3	276	6600	3	307	7344	3	337	8064
4	185	4416	4	216	5160	4	247	5904	4	277	6624	4	308	7368	4	338	8088
5	186	4440	5	217	5184	5	248	5928	5	278	6648	5	309	7392	5	339	8112
6	187	4464	6	218	5208	6	249	5952	6	279	6672	6	310	7416	6	340	8136
7	188	4488	7	219	5232	7	250	5976	7	280	6696	7	311	7440	7	341	8160
8	189	4512	8	220	5256	8	251	6000	8	281	6720	8	312	7464	8	342	8184
9	190	4536	9	221	5280	9	252	6024	9	282	6744	9	313	7488	9	343	8208
10	191	4560	10	222	5304	10	253	6048	10	283	6768	10	314	7512	10	344	8232
11	192	4584	11	223	5328	11	254	6072	11	284	6792	11	315	7536	11	345	8256
12	193	4608	12	224	5352	12	255	6096	12	285	6816	12	316	7560	12	346	8280
13	194	4632	13	225	5376	13	256	6120	13	286	6840	13	317	7584	13	347	8304
14	195	4656	14	226	5400	14	257	6144	14	287	6864	14	318	7608	14	348	8328
15	196	4680	15	227	5424	15	258	6168	15	288	6888	15	319	7632	15	349	8352
16	197	4704	16	228	5448	16	259	6192	16	289	6912	16	320	7656	16	350	8376
17	198	4728	17	229	5472	17	260	6216	17	290	6936	17	321	7680	17	351	8400
18	199	4752	18	230	5496	18	261	6240	18	291	6960	18	322	7704	18	352	8424
19	200	4776	19	231	5520	19	262	6264	19	292	6984	19	323	7728	19	353	8448
20	201	4800	20	232	5544	20	263	6288	20	293	7008	20	324	7752	20	354	8472
21	202	4824	21	233	5568	21	264	6312	21	294	7032	21	325	7776	21	355	8496
22	203	4848	22	234	5592	22	265	6336	22	295	7056	22	326	7800	22	356	8520
23	204	4872	23	235	5616	23	266	6360	23	296	7080	23	327	7824	23	357	8544
24	205	4896	24	236	5640	24	267	6384	24	297	7104	24	328	7848	24	358	8568
25	206	4920	25	237	5664	25	268	6408	25	298	7128	25	329	7872	25	359	8592
26	207	4944	26	238	5688	26	269	6432	26	299	7152	26	330	7896	26	360	8616
27	208	4968	27	239	5712	27	270	6456	27	300	7176	27	331	7920	27	361	8640
28	209	4992	28	240	5736	28	271	6480	28	301	7200	28	332	7944	28	362	8664
29	210	5016	29	241	5760	29	272	6504	29	302	7224	29	333	7968	29	363	8688
30	211	5040	30	242	5784	30	273	6528	30	303	7248	30	334	7992	30	364	8712
31	212	5064	31	243	5808				31	304	7272				31	364	8736

SECTION 2

Individual Site and Record Information Tables

The following tables provide information about the location, dates, and basic statistics of the data records. Each table documents a single instrument site, except in the case of one instrument. The data record for site IES86H1 consists of two portions which are separated by a two month data gap. Thus two tables, one for each portion, are presented for this instrument.

General site information, such as position, bottom depth, and launch and recovery times, are given first. These are followed by details about the travel time, bottom pressure and temperature records plotted in Sections 3 and 4. For each plot, the times associated with the first and last data point are supplied. All yearhours are referenced to 0000 GMT on January 1, 1986 as indicated by the two-digit number, 86, of the site name. Measurements made during the calendar year prior to the reference date are given as negative yearhours.

The first order statistics (minimum, maximum, mean, and standard deviation) were calculated for the half-hourly and the 40 HRLP records for each variable. These are also presented in the following tables.

Table 3. Site and Record Information for
IES86G1

Serial Number: 044
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

Position: 38°09.01 N, 70°26.06 W   Depth: 3505 m

	DATE	GMT	CRUISE
LAUNCH:	May 16, 1985	1439	EN130
RECOVERY:	Jun 23, 1986	0629	BART1307

TRAVEL TIME RECORDS
(Fig. 3.1)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	153155	-5504.4681
LAST DATA POINT:	Jun 23, 1986	043155	4156.5319

Number of Points: 19323
Sampling Interval: 0.50 hrs

Minimum τ = 4.61105 s   Mean = 4.62917 s
Maximum τ = 4.64213 s   Standard Deviation = 0.00700 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.1)

Z_{12} Conversion equation: $Z_{12} = (-19000\,ms^{-1})\,(\tau_d) + B$
where B = 88250.27 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	000000	-5472.00
LAST DATA POINT:	Jun 21, 1986	180000	4122.00

Number of Points: 1600
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 81.92 m   Mean = 296.23 m
Maximum Z_{12} = 624.67 m   Standard Deviation = 135.93 m

Table 4. Site and Record Information for
PIES86G2

Serial Number: 054
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: Pressure and Temperature

Position: 37°53.94 N   Depth: 3870 m
70°18.02 W

	DATE	GMT	CRUISE
LAUNCH:	May 16, 1985	1211	EN130
RECOVERY:	Jun 23, 1986	1037	BART1307

TRAVEL TIME RECORDS
(Fig. 3.2)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	131135	-5506.8070
LAST DATA POINT:	Jun 23, 1986	084135	4160.6930

Number of Points: 19336
Sampling Interval: 0.50 hrs

Minimum τ = 0.29664 s   Mean = 0.31202 s
Maximum τ = 0.32904 s   Standard Deviation = 0.00848 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.1)

Z_{12} Conversion equation: $Z_{12} = (-19000 ms^{-1}) (\tau_d) + B$
where $B = 6333.98$ m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	000000	-5472.00
LAST DATA POINT:	Jun 22, 1986	000000	4128.00

Number of Points: 1601
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 109.88 m   Mean = 406.02 m
Maximum Z_{12} = 682.32 m   Standard Deviation = 160.35 m

PIES86G2 (continued)

MEASURED PRESSURE RECORDS
(Fig. 4.1)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	131135	-5506.8070
LAST DATA POINT:	Jun 23, 1986	084135	4160.6930

Number of points: 19336
Sampling Interval: 0.50 hrs

Minimum = 3910.005 dbar
Maximum = 3914.663 dbar
Mean = 3913.641 dbar
Standard devition = 0.347 dbar

RESIDUAL PRESSURE RECORDS
(Fig. 5.1)

$$P_{residual} = P_{measured} - \text{MEAN} - \text{DRIFT} - \text{TIDE}$$

DRIFT = $P_1[1 - \exp(P_2 t)] + P_4 t + P_3$
where t = Time of sample in hours, starting with t = 13.0 hrs for the first data point

P_1 = 0.682418 dbar
P_2 = -0.013266 dbar
P_3 = -0.841680 dbar
P_4 = 0.000034 dbar

TIDE calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	.43109	.10244	.09180	.02216	.08538	.06475	.02799	.01430
G°:	353.19	337.08	20.24	21.94	179.19	182.89	179.69	181.87

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 17, 1985	011135	-5494.8070
LAST DATA POINT:	Jun 23, 1986	084135	4160.6930

Number of points: 19312
Sampling Interval: 0.50 hrs

Minimum = -0.1445 dbar
Maximum = 0.1271 dbar
Mean = 0.0000 dbar
Standard Deviation = 0.0378 dbar

PIES86G2 (continued)

40HRLP PRESSURE RECORDS
(Fig. 8.)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	120000	-5460.0000
LAST DATA POINT:	Jun 22, 1986	000000	4128.0000

Number of points: 1599
Sampling Interval: 6.00 hrs

Minimum = -0.1271 dbar
Maximum = 0.1129 dbar
Mean = 0.0000 dbar
Standard devition = 0.0351 dbar

TEMPERATURE RECORDS
(Fig. 6.1)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	131135	-5506.8070
LAST DATA POINT:	Jun 23, 1986	084135	4160.6930

Number of points: 19336
Sampling Interval: 0.50 hrs

Minimum = 2.208 °C
Maximum = 4.348 °C
Mean = 2.249 °C
Standard Deviation = 0.065 °C

40HRLP TEMPERATURE RECORDS
(Fig. 9.)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	120000	-5460.0000
LAST DATA POINT:	Jun 22, 1986	000000	4128.0000

Number of points: 1599
Sampling Interval: 6.00 hrs

Minimum 2.208 °C
Maximum 2.311 °C
Mean = 2.250 °C
Standard deviation = 0.023 °C

Table 5. Site and Record Information for
PIES86G4

Serial Number: 053
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: Pressure and Temperature

Position: 37°23.95 N
70°01.08 W
Depth: 4240 m

	DATE	GMT	CRUISE
LAUNCH:	May 16, 1985	0515	EN130
RECOVERY:	Jun 23, 1986	1848	BART1307

TRAVEL TIME RECORDS
(Fig. 3.3)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	060105	-5513.4820
LAST DATA POINT:	Jun 23, 1986	170105	4169.0180

Number of Points: 19366
Sampling Interval: 0.50 hrs

Minimum τ = 0.40532 s
Maximum τ = 0.44008 s
Mean = 0.41399 s
Standard Deviation = 0.00557 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.1)

Z_{12} Conversion equation: $Z_{12} = (-19000\,ms^{-1})\,(\tau_d) + B$
where B = 8528.94 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 17, 1985	120000	-5484.00
LAST DATA POINT:	Jun 22, 1986	060000	4134.00

Number of Points: 1604
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 195.50 m
Maximum Z_{12} = 798.30 m
Mean = 662.84 m
Standard Deviation = 105.45 m

PIES86G4 (continued)

MEASURED PRESSURE RECORDS
(Fig. 4.2)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	063105	-5513.4820
LAST DATA POINT:	Jun 23, 1986	170105	4169.0180

Number of points: 19366
Sampling Interval: 0.50 hrs

Minimum = 4314.505 dbar
Maximum = 4316.259 dbar
Mean = 4315.376 dbar
Standard devition = 0.330 dbar

RESIDUAL PRESSURE RECORDS
(Fig. 5.2)

$$P_{residual} = P_{measured} - \text{MEAN} - \text{DRIFT} - \text{TIDE}$$

DRIFT = $P_1[1 - \exp(P_2 t)] + P_3$
where t = Time of sample in hours, starting with t = 13.0 hrs for the first data point
P_1 = -24.796120 dbar
P_2 = - 0.0000005 dbar
P_3 = 0.083616 dbar

TIDE calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	.42937	.10248	.09231	.02234	.08378	.06473	.02766	.01369
G°:	353.59	337.10	21.22	22.92	178.82	183.19	179.44	181.98

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	183105	-5501.4820
LAST DATA POINT:	Jun 23, 1986	170105	4169.0180

Number of points: 19342
Sampling Interval: 0.50 hrs

Minimum = -0.1752 dbar
Maximum = 0.1209 dbar
Mean = 0.0000 dbar
Standard Deviation = 0.0468 dbar

PIES86G4 (continued)

40HRLP PRESSURE RECORDS
(Fig. 8.)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	060000	-5466.0000
LAST DATA POINT:	Jun 22, 1986	060000	4134.0000

Number of points: 1601
Sampling Interval: 6.00 hrs

Minimum = -0.1311 dbar
Maximum = 0.9375 dbar

Mean = 0.0000 dbar
Standard devition = 0.0445 dbar

TEMPERATURE RECORDS
(Fig. 6.2)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	063105	-5513.4820
LAST DATA POINT:	Jun 23, 1986	170105	4169.0180

Number of points: 19366
Sampling Interval: 0.50 hrs

Minimum = 2.270 °C
Maximum = 7.904 °C

Mean = 2.297 °C
Standard Deviation = 0.085 °C

40HRLP TEMPERATURE RECORDS
(Fig. 9.)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	060000	-5466.0000
LAST DATA POINT:	Jun 22, 1986	060000	4134.0000

Number of points: 1601
Sampling Interval: 6.00 hrs

Minimum 2.272 °C
Maximum 2.340 °C

Mean = 2.298 °C
Standard deviation = 0.021 °C

Table 6. Site and Record Information for **IES86G5**

Serial Number: 036
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

Position: 37°10.05 N, 69°53.12 W   Depth: 4320 m

	DATE	GMT	CRUISE
LAUNCH:	May 16, 1985	0058	EN130
RECOVERY:	Jun 24, 1986	0032	BART1307

TRAVEL TIME RECORDS
(Fig. 3.4)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	021557	-5517.7342
LAST DATA POINT:	Jun 23, 1986	221557	4174.2658

Number of Points: 19385
Sampling Interval: 0.50 hrs

Minimum τ = 5.71260 s
Maximum τ = 5.74400 s
Mean = 5.71976 s
Standard Deviation = 0.00523 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.1)

Z_{12} Conversion equation: $Z_{12} = (-19000 ms^{-1}) (\tau_d) + B$
where $B = 109383.56$ m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 17, 1985	120000	-5484.00
LAST DATA POINT:	Jun 22, 1986	120000	4140.00

Number of Points: 1605
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 270.37 m
Maximum Z_{12} = 818.78 m
Mean = 707.35 m
Standard Deviation = 105.02 m

Table 7. Site and Record Information for
IES86G6

Serial Number: 045
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

Position: 36°56.00 N, 69°45.21 W   Depth: 4350 m

	DATE	GMT	CRUISE
LAUNCH:	May 10, 1985	1712	EN130
RECOVERY:	Jun 27, 1986	0259	BART1307

TRAVEL TIME RECORDS
(Fig. 3.5)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 10, 1985	183051	-5645.4858
LAST DATA POINT:	Jun 27, 1986	010051	4249.0142

Number of Points: 19790
Sampling Interval: 0.50 hrs

Minimum τ = 5.78633 s   Mean = 5.79655 s
Maximum τ = 5.82459 s   Standard Deviation = 0.00612 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.1)

Z_{12} Conversion equation: $Z_{12} = (-19000 \mathrm{ms}^{-1})(\tau_d) + B$
where $B = 110873.79$ m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 12, 1985	060000	-5610.00
LAST DATA POINT:	Jun 25, 1986	180000	4218.00

Number of Points: 1639
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 228.81 m   Mean = 738.38 m
Maximum Z_{12} = 908.99 m   Standard Deviation = 117.03 m

Table 8. Site and Record Information for
PIES86G7

Serial Number: 058
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 24
Additional Sensors: Pressure and Temperature

Position: 36°40.97 N   Depth: 4435 m
69°36.99 W

	DATE	GMT	CRUISE
LAUNCH:	May 17, 1985	1251	EN130
RECOVERY:	Jun 27, 1986	0610	BART1307

TRAVEL TIME RECORDS
(Fig. 3.6)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 17, 1985	140105	-5481.9820
LAST DATA POINT:	Jun 27, 1986	040105	4252.0180

Number of Points: 19469
Sampling Interval: 0.50 hrs

Minimum τ = 0.26647 s   Mean = 0.27727 s
Maximum τ = 0.30894 s   Standard Deviation = 0.00687 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.1)

Z_{12} Conversion equation: $Z_{12} = (-19000 \mathrm{ms}^{-1})(\tau_d) + B$
where B = 6013.60 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 19, 1985	000000	-5448.00
LAST DATA POINT:	Jun 25, 1986	180000	4218.00

Number of Points: 1612
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 180.80 m   Mean = 745.16 m
Maximum Z_{12} = 925.94 m   Standard Deviation = 130.46 m

PIES86G7 (continued)

MEASURED PRESSURE RECORDS
(Fig. 4.3)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 17, 1985	140105	-5481.9820
LAST DATA POINT:	Jun 27, 1986	040105	4252.0180

Number of points: 19469
Sampling Interval: 0.50 hrs

Minimum = 4521.095 dbar
Maximum = 4522.963 dbar

Mean = 4521.002 dbar
Standard devition = 0.327 dbar

RESIDUAL PRESSURE RECORDS
(Fig. 5.3)

$$P_{residual} = P_{measured} - \text{MEAN} - \text{DRIFT} - \text{TIDE}$$

DRIFT = $P_1[1 - \exp(P_2 t)] + P_3$
where t = Time of sample in hours, starting with t = 13.0 hrs for the first data point
P_1 = 0.080787 dbar
P_2 = -0.000118 dbar
P_3 = -0.032655 dbar

TIDE calculated from the following constituents:

	M2	N2	S2	K2	K1	O1	P1	Q1
H (dbar):	.42548	.10119	.09202	.02231	.08210	.06316	.02708	.01344
G°:	353.93	337.67	21.89	23.75	179.68	184.06	180.35	182.38

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	020105	-5469.9820
LAST DATA POINT:	Jun 27, 1986	040105	4252.0180

Number of points: 19445
Sampling Interval: 0.50 hrs

Minimum = -0.2105 dbar
Maximum = 0.3257 dbar

Mean = 0.0000 dbar
Standard Deviation = 0.0588 dbar

PIES86G7 (continued)

40HRLP PRESSURE RECORDS
(Fig. 8.)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 19, 1985	120000	-5436.0000
LAST DATA POINT:	Jun 25, 1986	180000	4218.0000

Number of points: 1610
Sampling Interval: 6.00 hrs

Minimum = -0.1943 dbar
Maximum = 0.2259 dbar

Mean = 0.0000 dbar
Standard devition = 0.0567 dbar

TEMPERATURE RECORDS
(Fig. 6.3)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 17, 1985	140105	-5481.9820
LAST DATA POINT:	Jun 27, 1986	040105	4252.0180

Number of points: 19469
Sampling Interval: 0.50 hrs

Minimum = 2.382 °C
Maximum = 6.871 °C

Mean = 2.461 °C
Standard Deviation = 0.083 °C

40HRLP TEMPERATURE RECORDS
(Fig. 9.)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 19, 1985	120000	-5436.0000
LAST DATA POINT:	Jun 25, 1986	180000	4218.0000

Number of points: 1610
Sampling Interval: 6.00 hrs

Minimum 2.384 °C
Maximum 2.506 °C

Mean = 2.463 °C
Standard deviation = 0.022 °C

Table 9. Site and Record Information for
IES86G8

Serial Number: 061
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

Position: 36°26.05 N, 69°29.01 W
Depth: 4477 m

	DATE	GMT	CRUISE
LAUNCH:	May 17, 1985	1032	EN130
RECOVERY:	Jun 27, 1986	0922	BART1307

TRAVEL TIME RECORDS
(Fig. 3.7)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 17, 1985	114625	-5484.2264
LAST DATA POINT:	Jun 27, 1986	071625	4255.2736

Number of Points: 19480
Sampling Interval: 0.50 hrs

Minimum τ = 5.91908 s
Maximum τ = 5.96106 s
Mean = 5.92850 s
Standard Deviation = 0.00683 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.1)

Z_{12} Conversion equation: $Z_{12} = (-19000\text{ms}^{-1})(\tau_d) + B$
where B = 113410.56 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	180000	-5454.00
LAST DATA POINT:	Jun 26, 1986	000000	4224.00

Number of Points: 1614
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 182.10 m
Maximum Z_{12} = 932.25 m
Mean = 768.13 m
Standard Deviation = 136.32 m

Table 10. Site and Record Information for
IES86H1
PART1

Serial Number: 060
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

Position: 38°06.15 N Depth: 3860 m
69°33.78 W

	DATE	GMT	CRUISE
LAUNCH:	May 16, 1985	1834	EN130
RECOVERY:	Jul 13, 1986	0135	BART1307

TRAVEL TIME RECORDS
(Fig. 3.8)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	193116	-5500.4788
LAST DATA POINT:	Nov 24, 1985	173116	-844.4788

Number of Points: 9213
Sampling Interval: 0.50 hrs

Minimum τ = 0.09896 s Mean = 0.11613 s
Maximum τ = 0.12644 s Standard Deviation = 0.00693 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.2)

Z_{12} Conversion equation: $Z_{12} = (-19000 ms^{-1})(\tau_d) + B$
where B = 2464.62 m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	060000	-5466.00
LAST DATA POINT:	Nov 23, 1985	120000	- 924.00

Number of Points: 758
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 100.33 m Mean = 254.15 m
Maximum Z_{12} = 562.25 m Standard Deviation = 120.21 m

Table 11. Site and Record Information for
IES86H1
PART2

Serial Number: 060
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

Position: 38°06.15 N   Depth: 3860 m
69°33.78 W

	DATE	GMT	CRUISE
LAUNCH:	May 16, 1985	1834	EN130
RECOVERY:	Jul 13, 1986	0135	BART1307

TRAVEL TIME RECORDS
(Fig. 3.8)

	DATE	GMT	YEARHOUR
1st DATA POINT:	Jan 27, 1986	200116	644.0212
LAST DATA POINT:	Jul 12, 1986	213116	4629.5212

Number of Points: 7972
Sampling Interval: 0.50 hrs

Maximum τ = 0.09828 s   Mean = 0.11390 s
Minimum τ = 0.12652 s   Standard Deviation = 0.00787 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.2)

Z_{12} Conversion equation: $Z_{12} = (-19000 ms^{-1}) (\tau_d) + B$
where $B = 2464.62$ m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	Jan 29, 1986	060000	678.00
LAST DATA POINT:	Jul 11, 1986	120000	4596.00

Number of Points: 654
Sampling Interval: 6.00 hrs

Maximum Z_{12} = 86.47 m   Mean = 299.33 m
Maximum Z_{12} = 580.60 m   Standard Deviation = 143.70 m

Table 12. Site and Record Information for
IES86H2

Serial Number: 041
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

Position: 37°34.09 N
69°17.08 W

Depth: 4185 m

	DATE	GMT	CRUISE
LAUNCH:	May 16, 1985	2246	EN130
RECOVERY:	Jul 12, 1986	1840	BART1307

TRAVEL TIME RECORDS
(Fig. 3.9)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 16, 1985	234525	-5496.2431
LAST DATA POINT:	Jul 12, 1986	164525	4624.7569

Number of Points: 20243
Sampling Interval: 0.50 hrs

Minimum τ = 5.53514 s
Maximum τ = 5.57518 s

Mean = 5.54947 s
Standard Deviation = 0.00856 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.2)

Z_{12} Conversion equation: $Z_{12} = (-19000 ms^{-1})(\tau_d) + B$
where $B = 106004.65$ m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	060000	-5466.00
LAST DATA POINT:	Jul 11, 1986	060000	4590.00

Number of Points: 1677
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 111.84 m
Maximum Z_{12} = 806.66 m

Mean = 563.90 m
Standard Deviation = 166.12 m

Table 13. Site and Record Information for
IES86H3

Serial Number: 043
Type of Travel Time Detector: TTC
Number of Pings per Sampling: 20
Additional Sensors: None

Position: 37°01.97 N
68°59.91 W
Depth: 4595 m

	DATE	GMT	CRUISE
LAUNCH:	May 17, 1985	0422	EN130
RECOVERY:	Jun 27, 1986	1525	BART1307

TRAVEL TIME RECORDS
(Fig. 3.10)

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 17, 1985	054618	-5490.2283
LAST DATA POINT:	Jun 27, 1986	131618	4261.2715

Number of Points: 19504
Sampling Interval: 0.50 hrs

Minimum τ = 6.07737 s
Maximum τ = 6.11928 s
Mean = 6.08951 s
Standard Deviation = 0.00870 s

40HRLP THERMOCLINE DEPTH RECORDS
(Fig. 7.2)

Z_{12} Conversion equation: $Z_{12} = (-19000\text{ms}^{-1})\ (\tau_d) + B$
where $B = 116385.65$ m
τ_d = Travel Time (sec) with tide removed

	DATE	GMT	YEARHOUR
1st DATA POINT:	May 18, 1985	120000	-5460.00
LAST DATA POINT:	Jun 26, 1986	060000	4230.00

Number of Points: 1616
Sampling Interval: 6.00 hrs

Minimum Z_{12} = 143.38 m
Maximum Z_{12} = 893.69 m
Mean = 683.79 m
Standard Deviation = 169.59 m

SECTION 3

Half-hourly Data For Each Instrument

Plots of the travel time records from each instrument are presented first. These are followed by the measured and residual pressure records and plots of the temperature records from the three instruments with the additional pressure and temperature sensors.

The time scale is the same for all plots, with each increment corresponding to 5 days. The axis begins on 0000 GMT of the first date labelled.

The vertical scale is consistent between instruments, with each increment corresponding to 5 msec for the travel time plots, 0.5 dbar for bottom pressure plots, 0.05 dbar for residual bottom pressure, and 0.02°C for the temperature plots.

The sampling interval is nominally 0.5 hours; the actual interval for each instrument is given in the tables of Section 2. The length and the start and end times of the data records are also given in these tables.

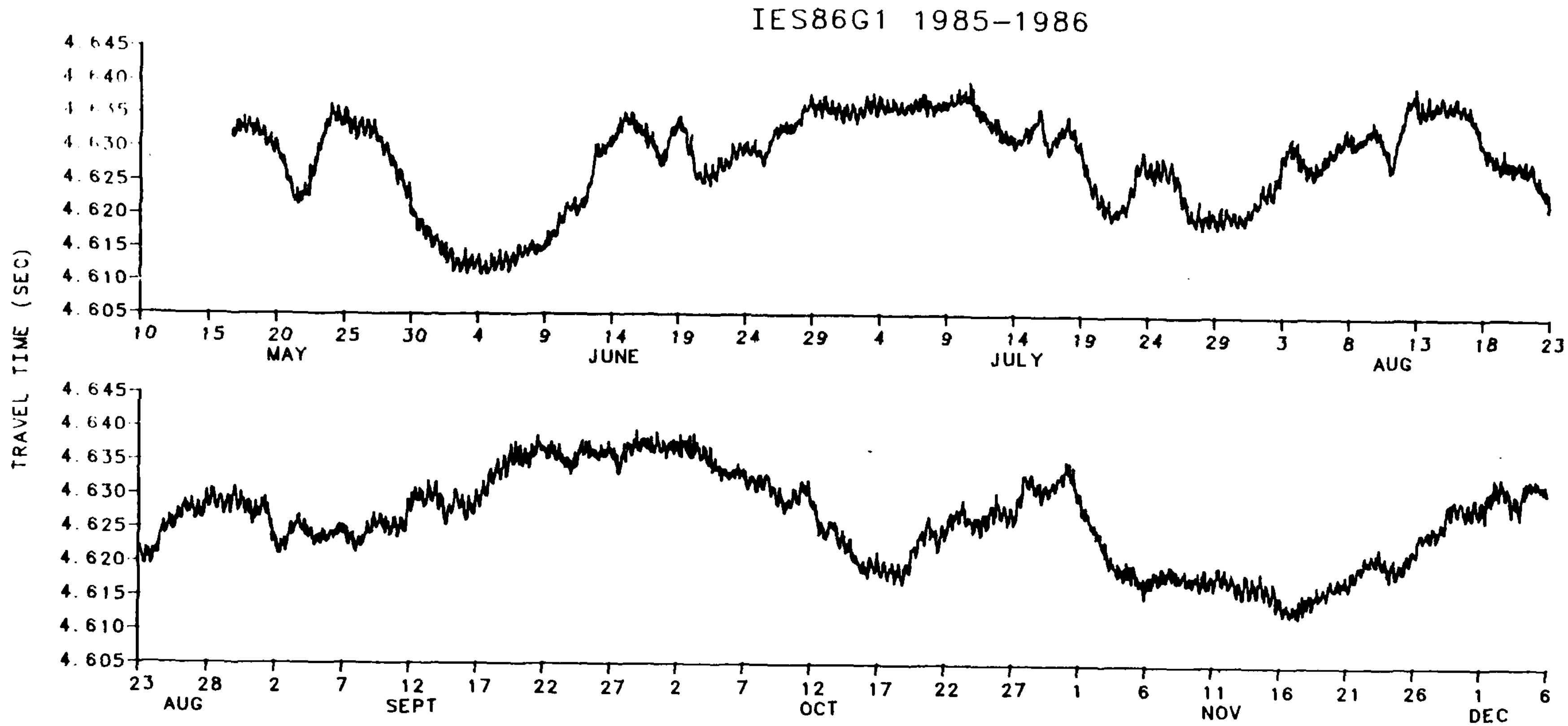


Figure 3.1 **Half-hourly travel time data from IES86G1**

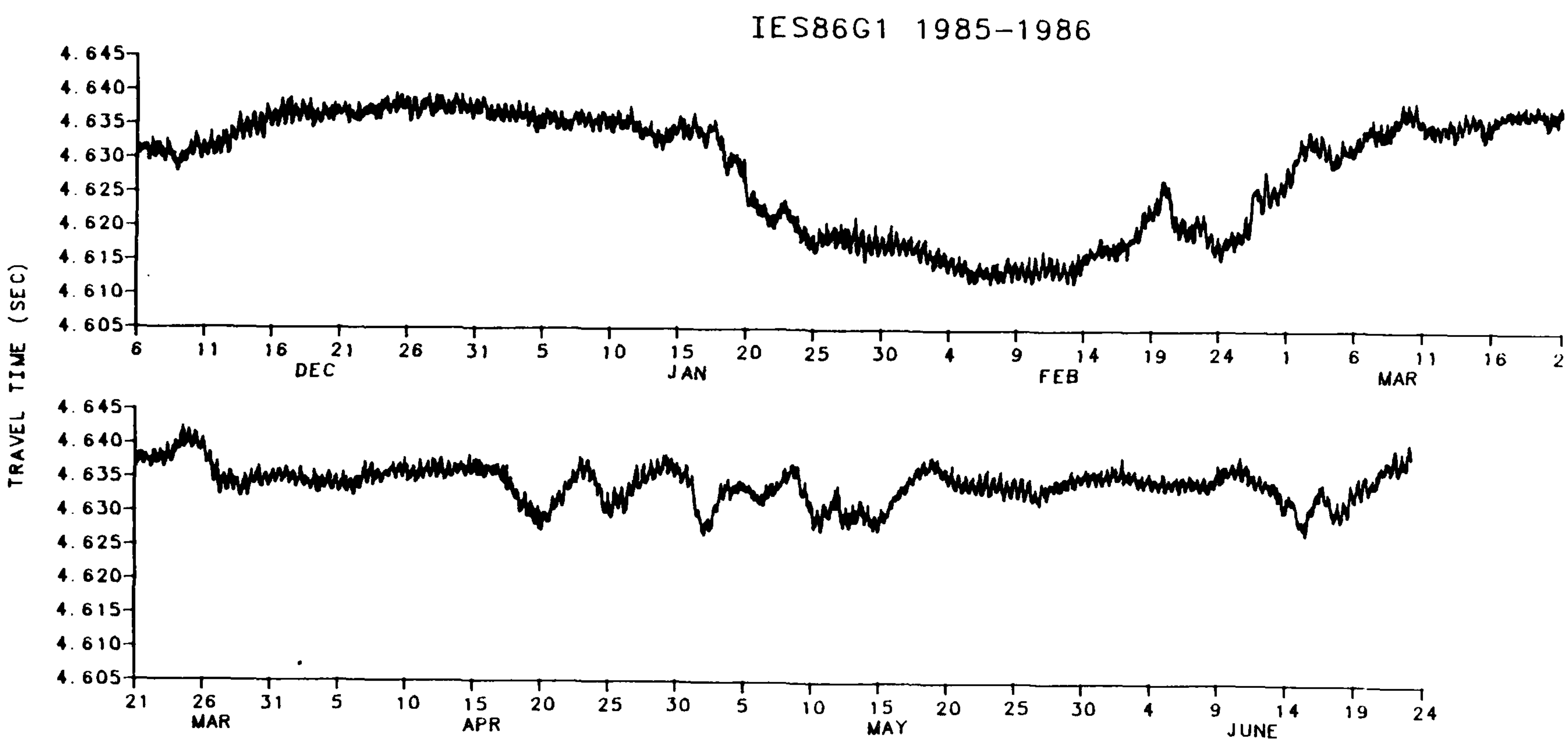

IES86G1 1985-1986
TRAVEL TIME (SEC)
4.645
4.640
4.635
4.630
4.625
4.620
4.615
4.610
4.605
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 3.1

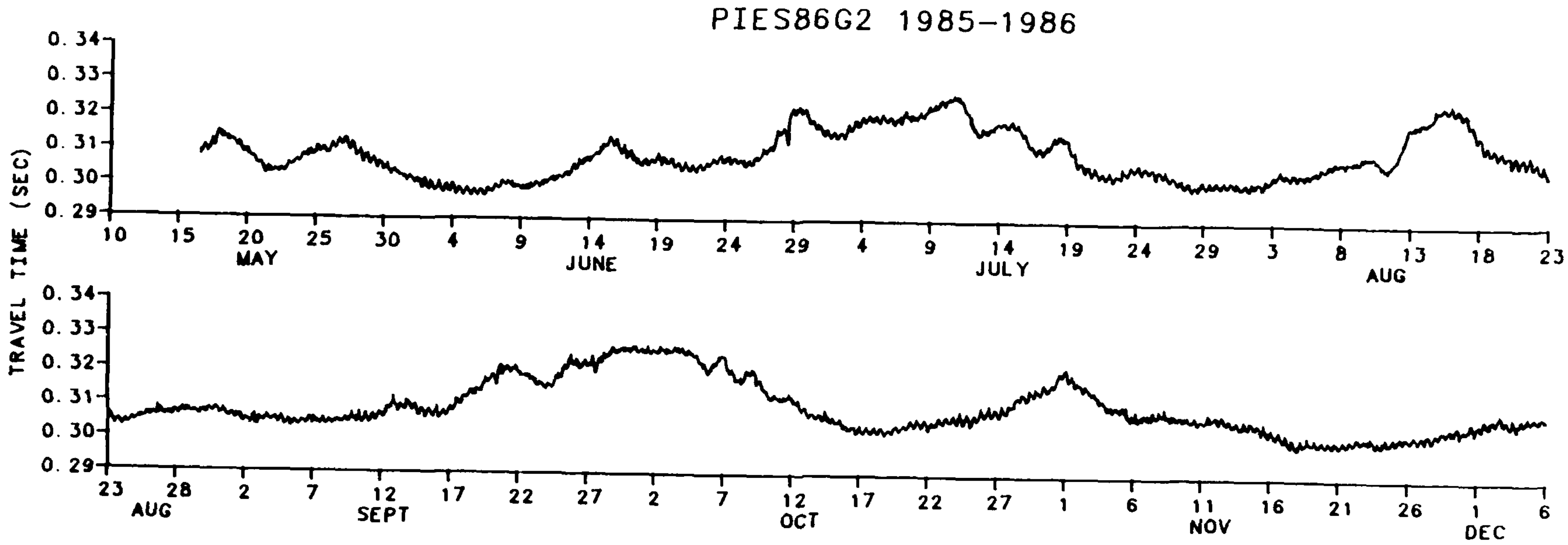


Figure 3.2 Half-hourly travel time data from PIES86G2

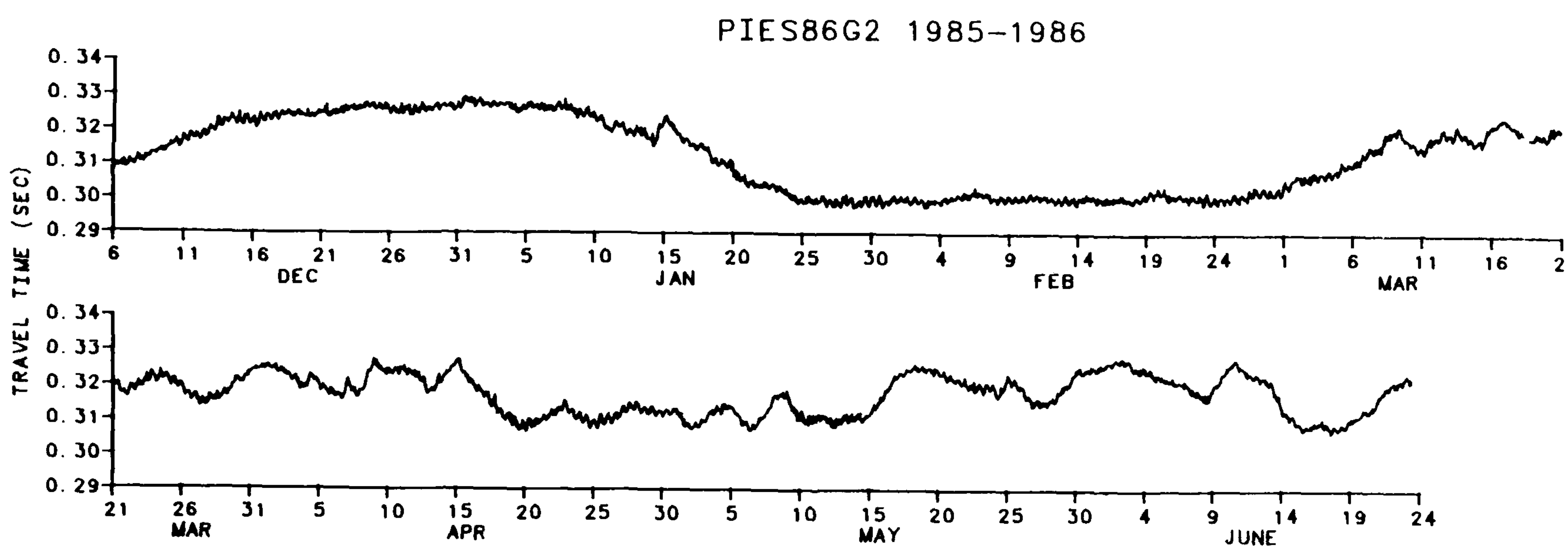

PIES86G2 1985–1986
TRAVEL TIME (SEC)
0.34
0.33
0.32
0.31
0.30
0.29
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 3.2

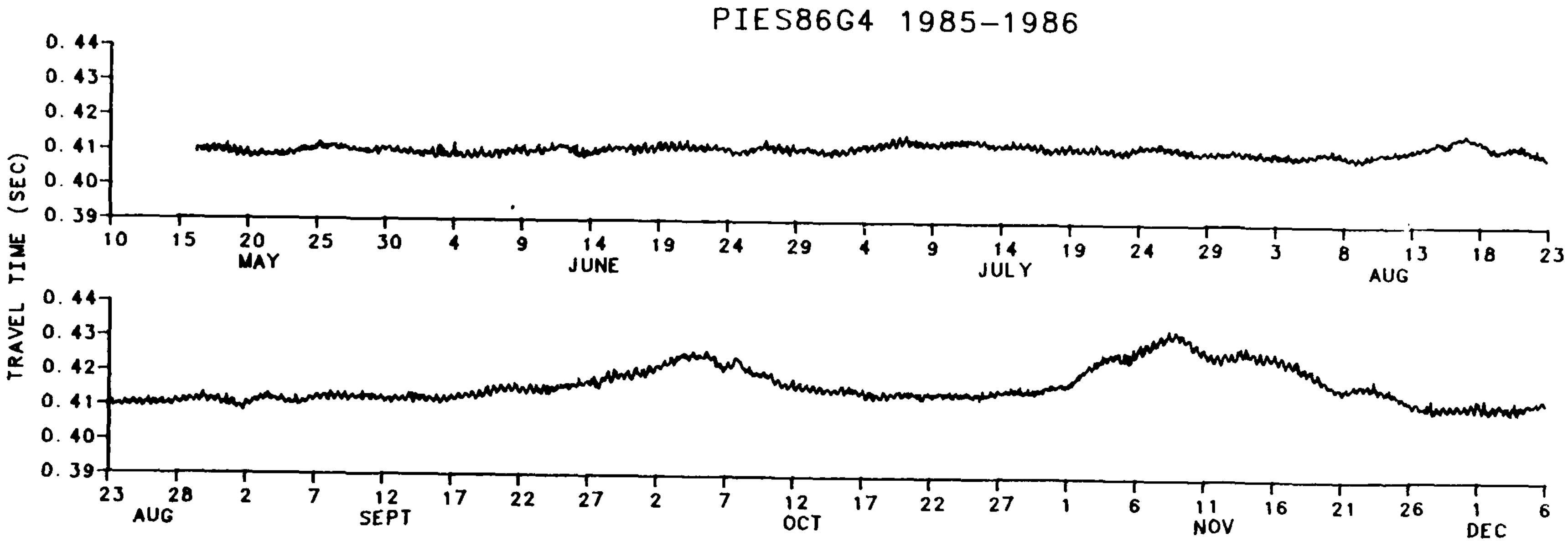


Figure 3.3 Half-hourly travel time data from PIES86G4

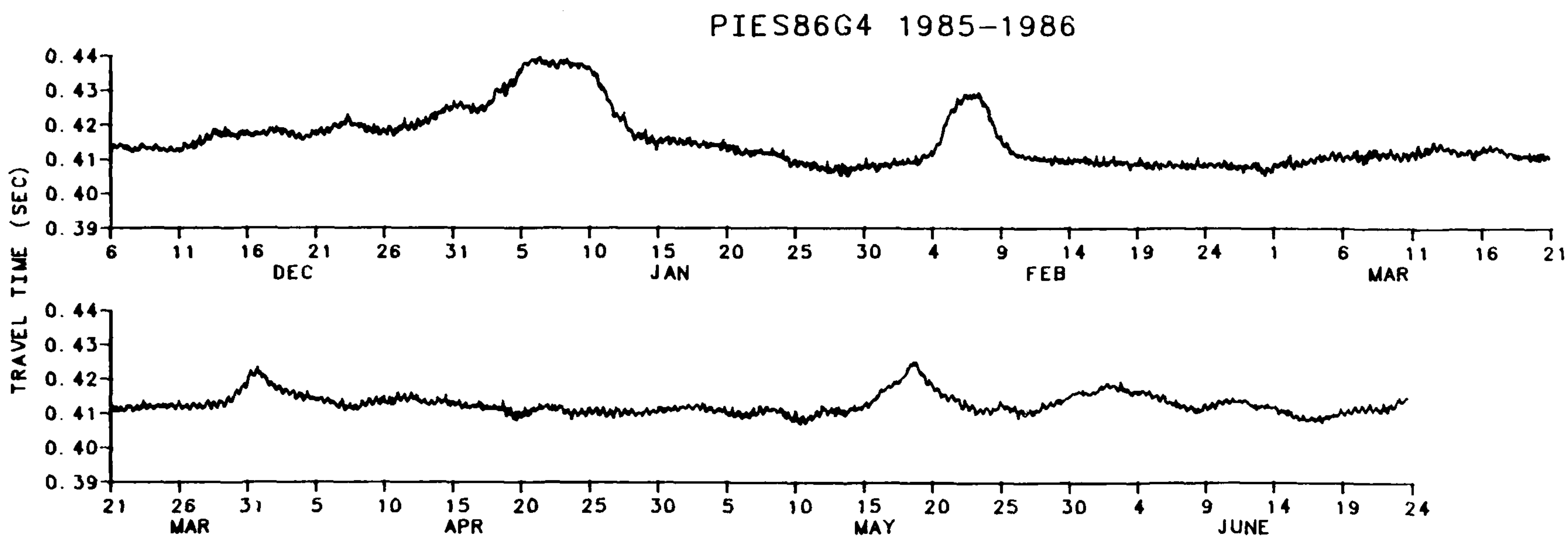

PIES86G4 1985-1986
TRAVEL TIME (SEC)
0.44
0.43
0.42
0.41
0.40
0.39
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 3.3

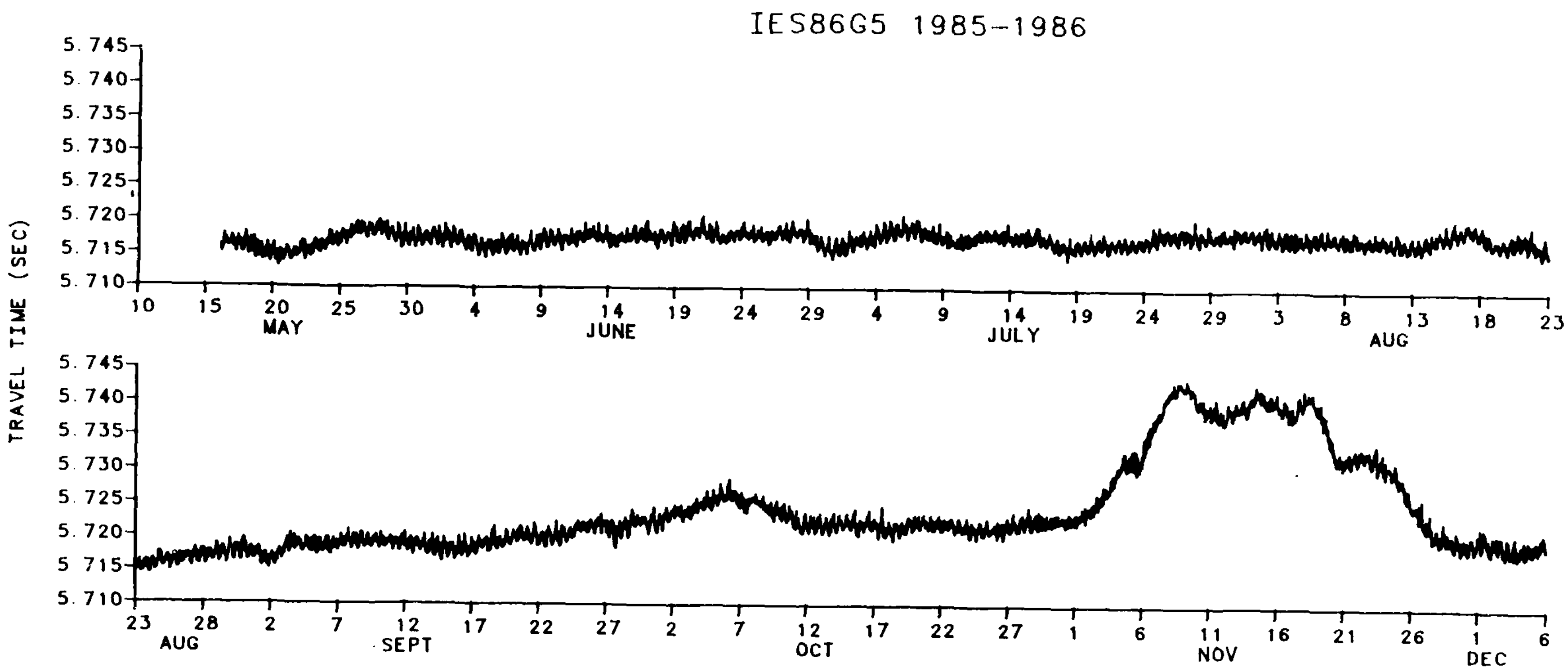


Figure 3.4 Half-hourly travel time data from IES86G5

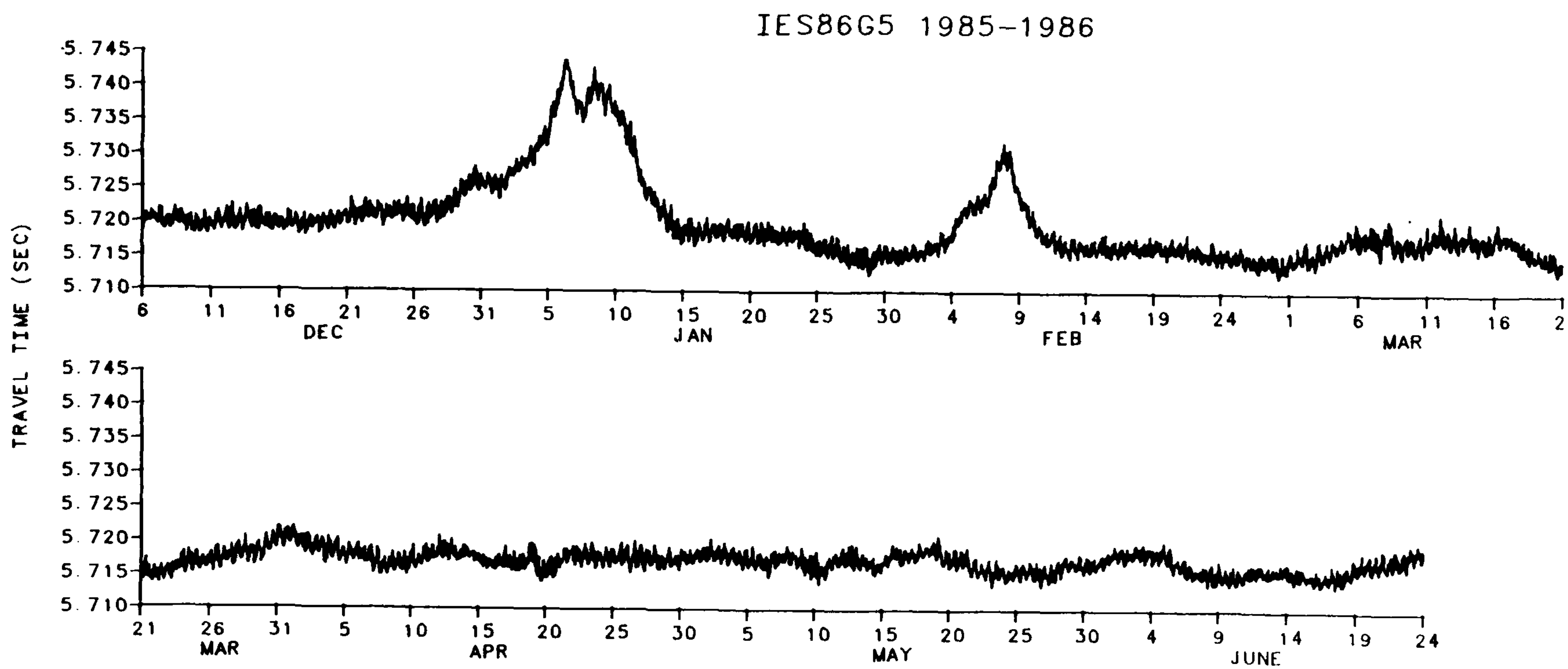

IES86G5 1985-1986
TRAVEL TIME (SEC)
5.745
5.740
5.735
5.730
5.725
5.720
5.715
5.710
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 3.4

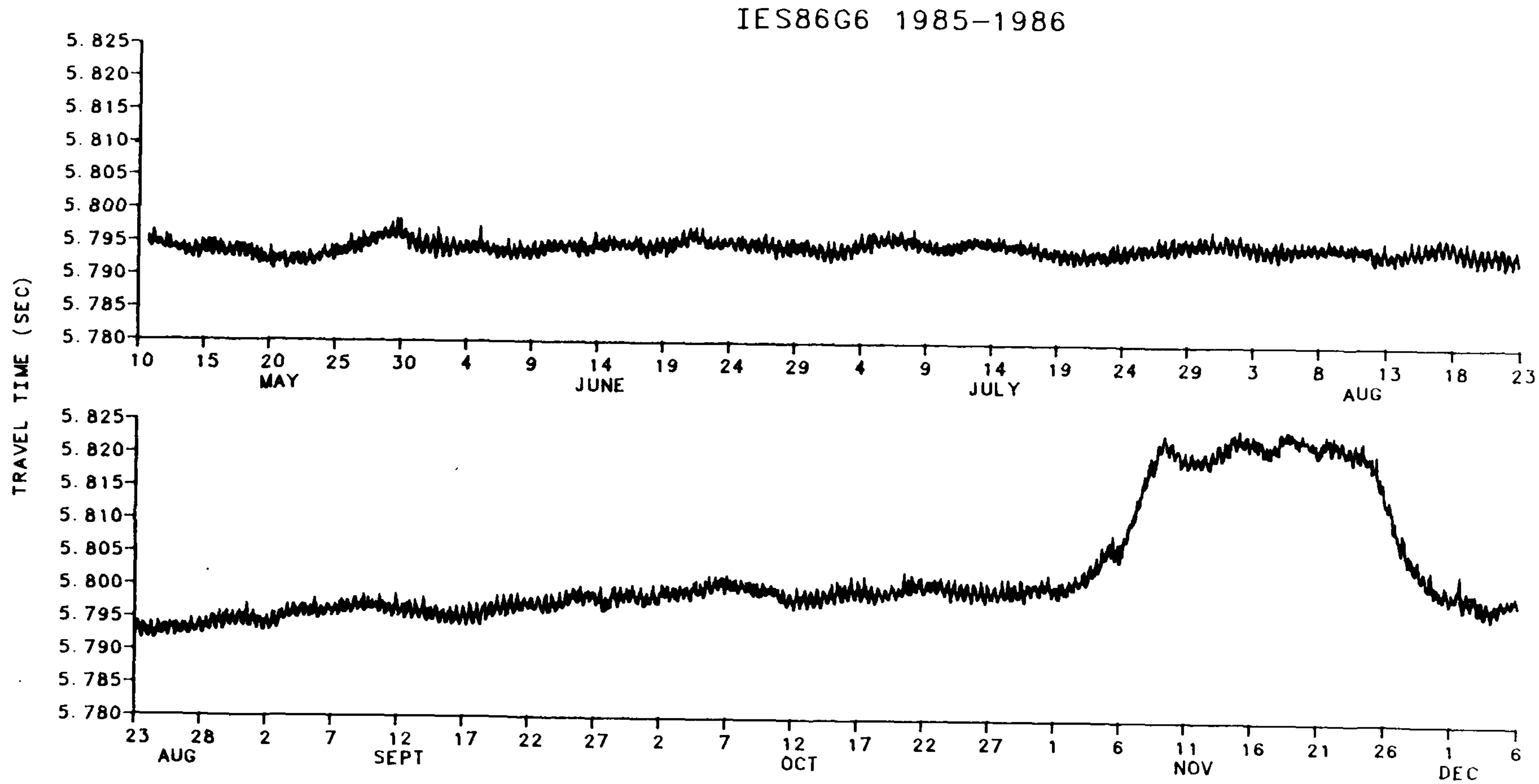


Figure 3.5 Half-hourly travel time data from IES86G6

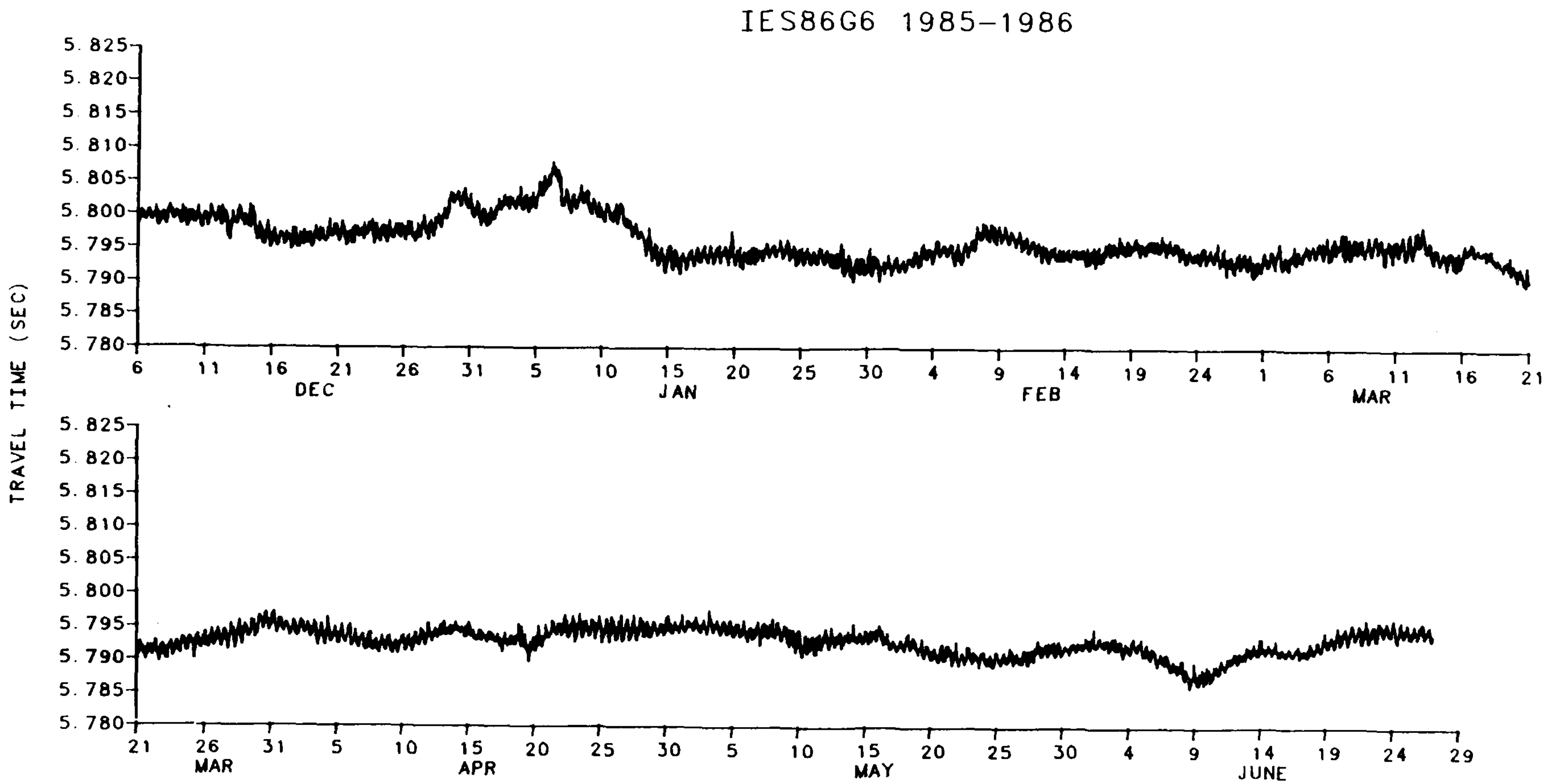

IES86G6 1985–1986
TRAVEL TIME (SEC)
5.825
5.820
5.815
5.810
5.805
5.800
5.795
5.790
5.785
5.780
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29
MAR
APR
MAY
JUNE

Figure 3.5

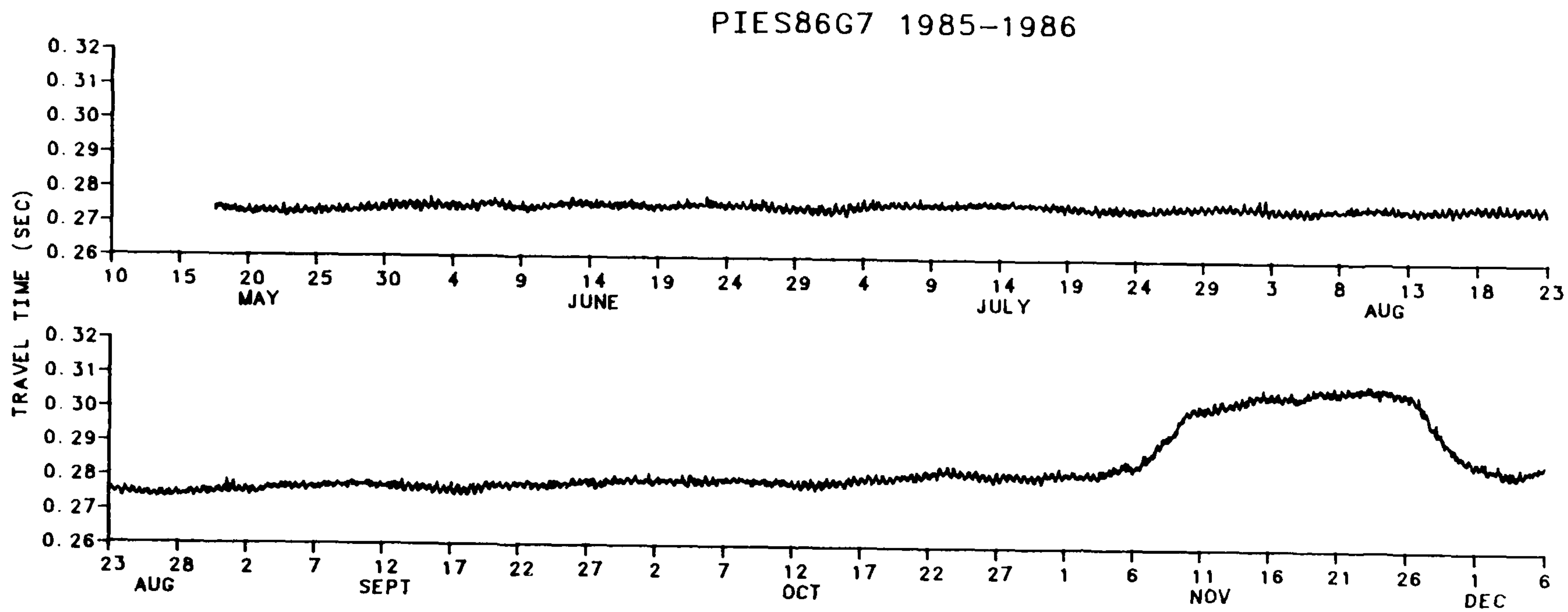


Figure 3.6 Half-hourly travel time data from PIES86G7

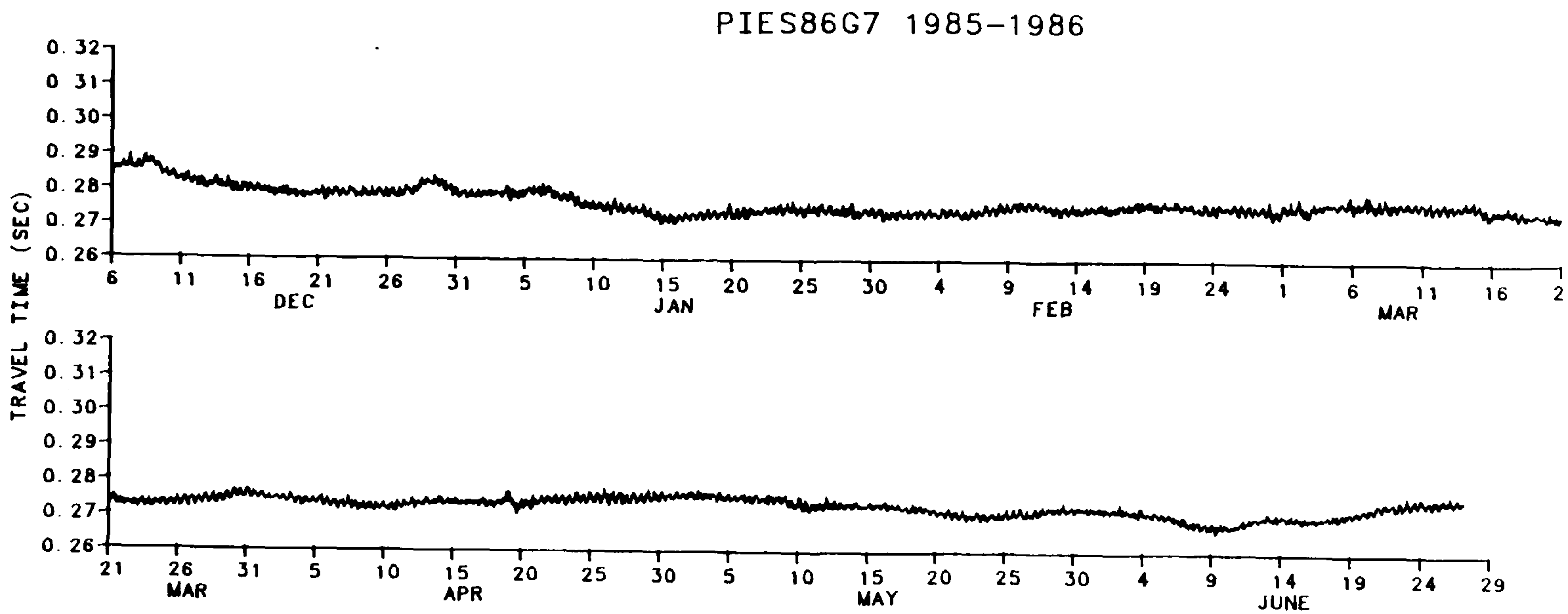

PIES86G7 1985-1986
TRAVEL TIME (SEC)
0. 32
0. 31
0. 30
0. 29
0. 28
0. 27
0. 26
6
11
16
21
26
31
5
10
15
20
25
30
4
9
14
19
24
1
6
11
16
21
DEC
JAN
FEB
MAR
21
26
31
5
10
15
20
25
30
5
10
15
20
25
30
4
9
14
19
24
29
MAR
APR
MAY
JUNE

Figure 3.6

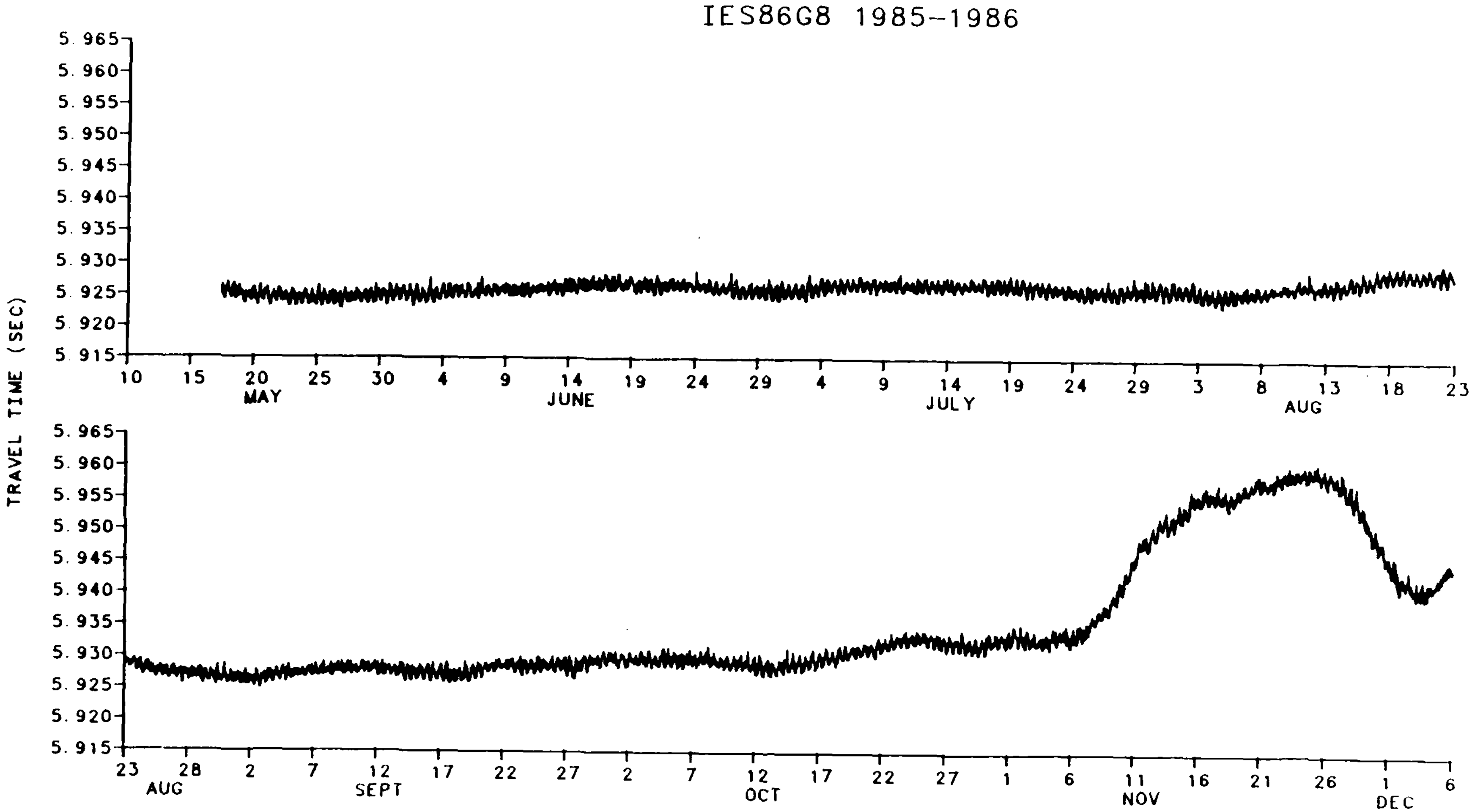
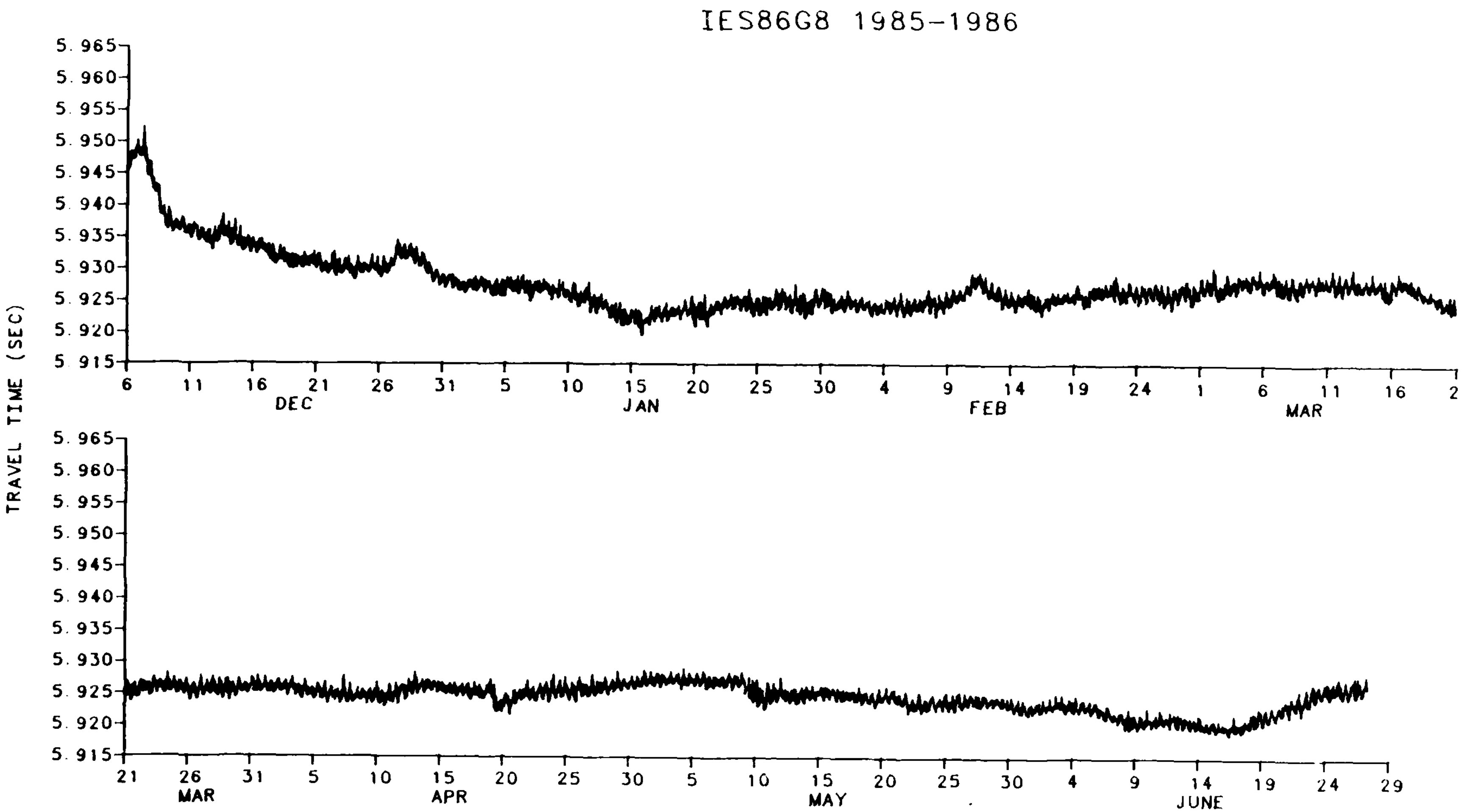


Figure 3.7 Half-hourly travel time data from IES86G8



IES86G8 1985-1986
TRAVEL TIME (SEC)
5.965
5.960
5.955
5.950
5.945
5.940
5.935
5.930
5.925
5.920
5.915
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29
MAR
APR
MAY
JUNE

Figure 3.7

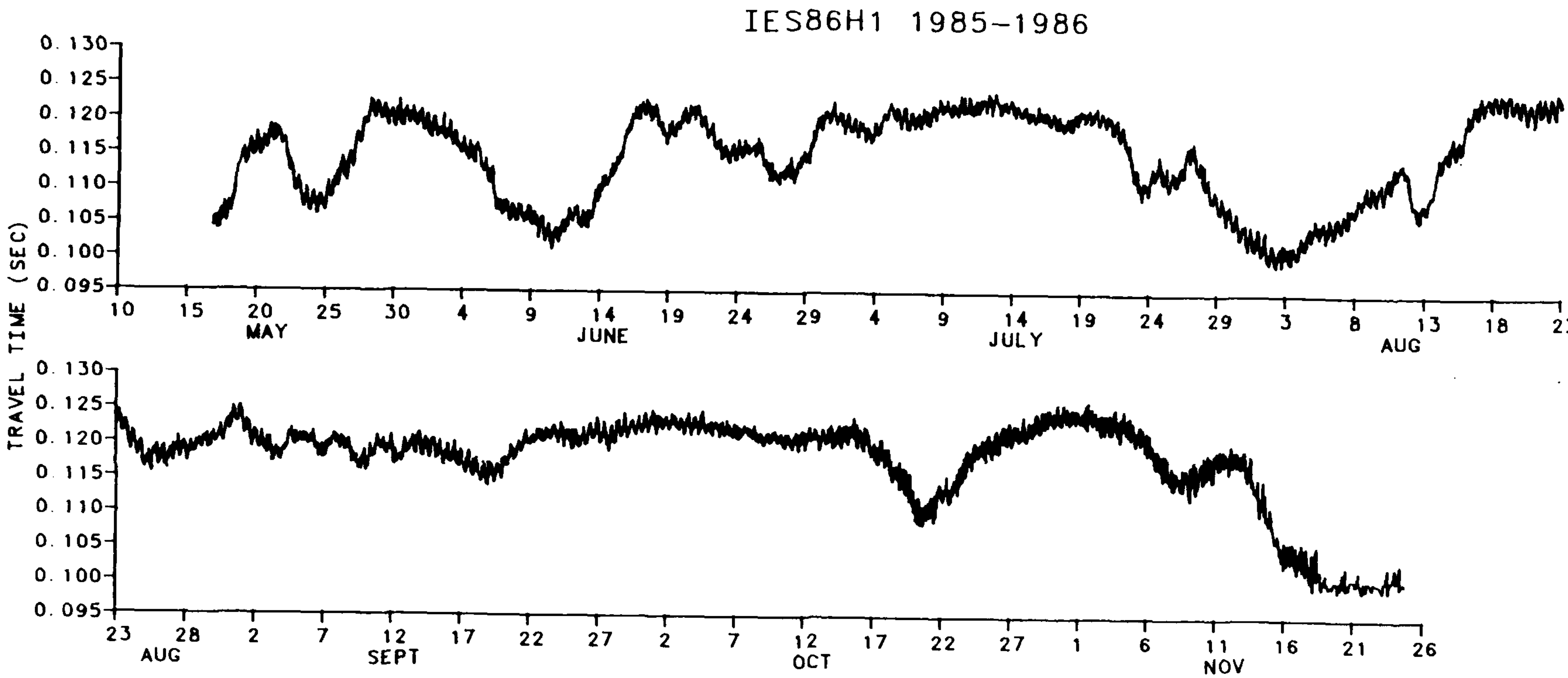
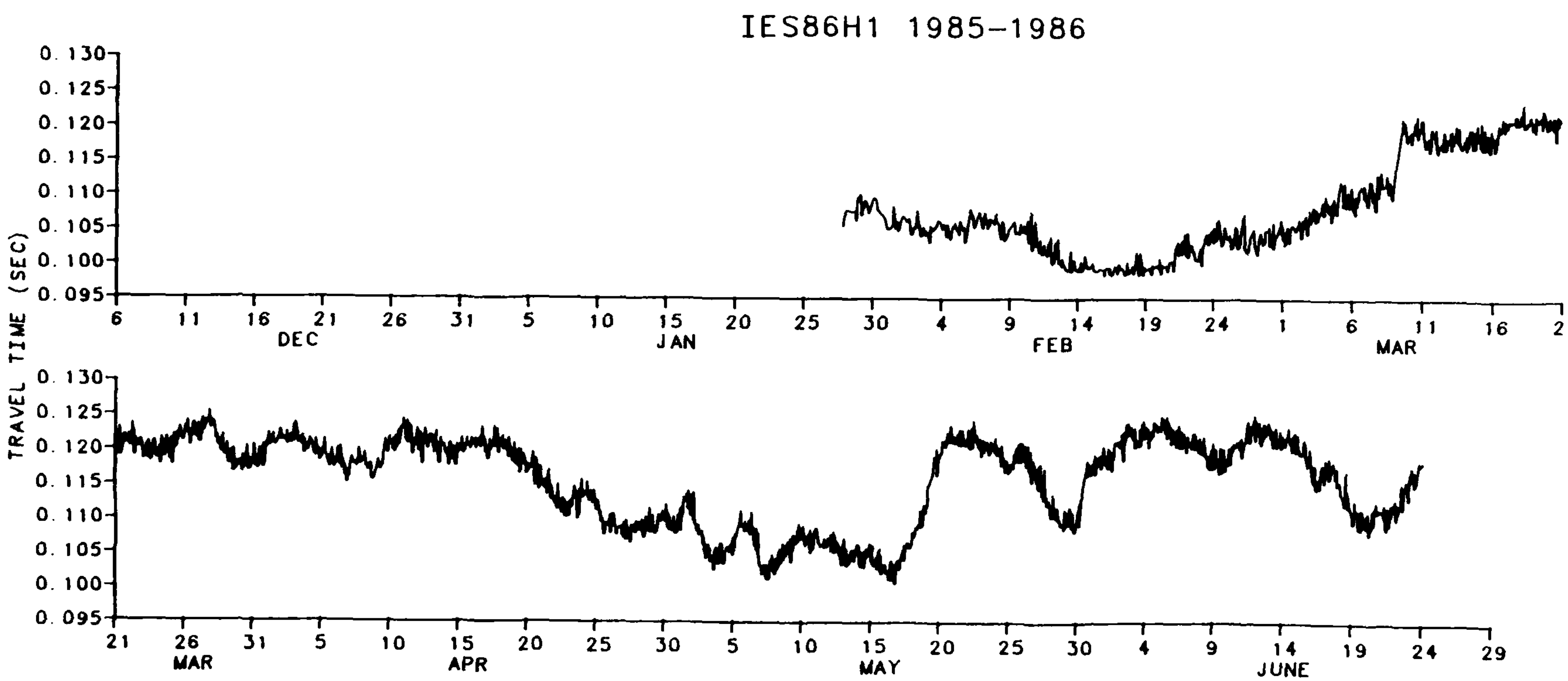


Figure 3.8 Half-hourly travel time data from IES86H1



IES86H1 1985–1986
TRAVEL TIME (SEC)
0.130
0.125
0.120
0.115
0.110
0.105
0.100
0.095
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29
MAR
APR
MAY
JUNE

Figure 3.8

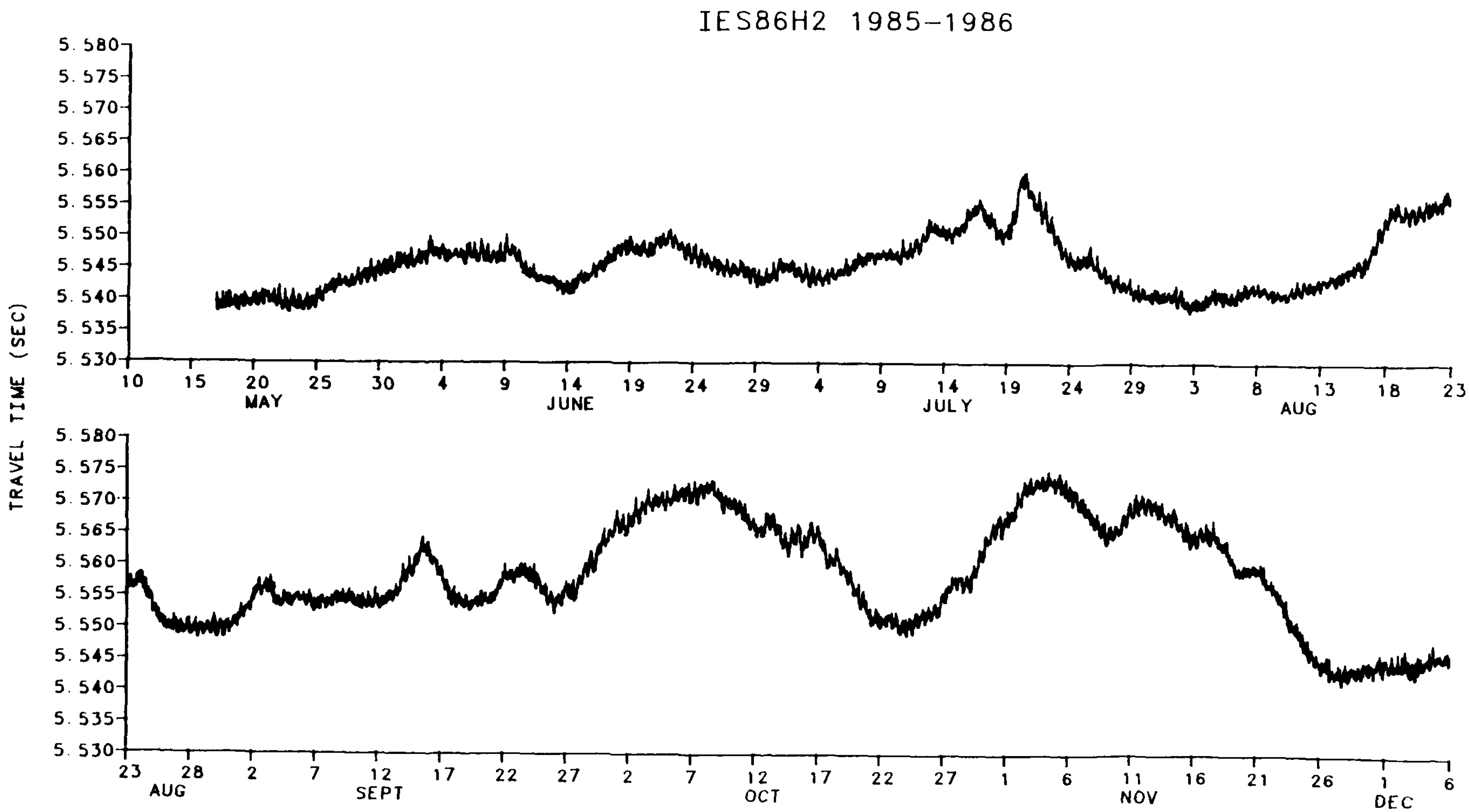


Figure 3.9 Half-hourly travel time data from IES86H2

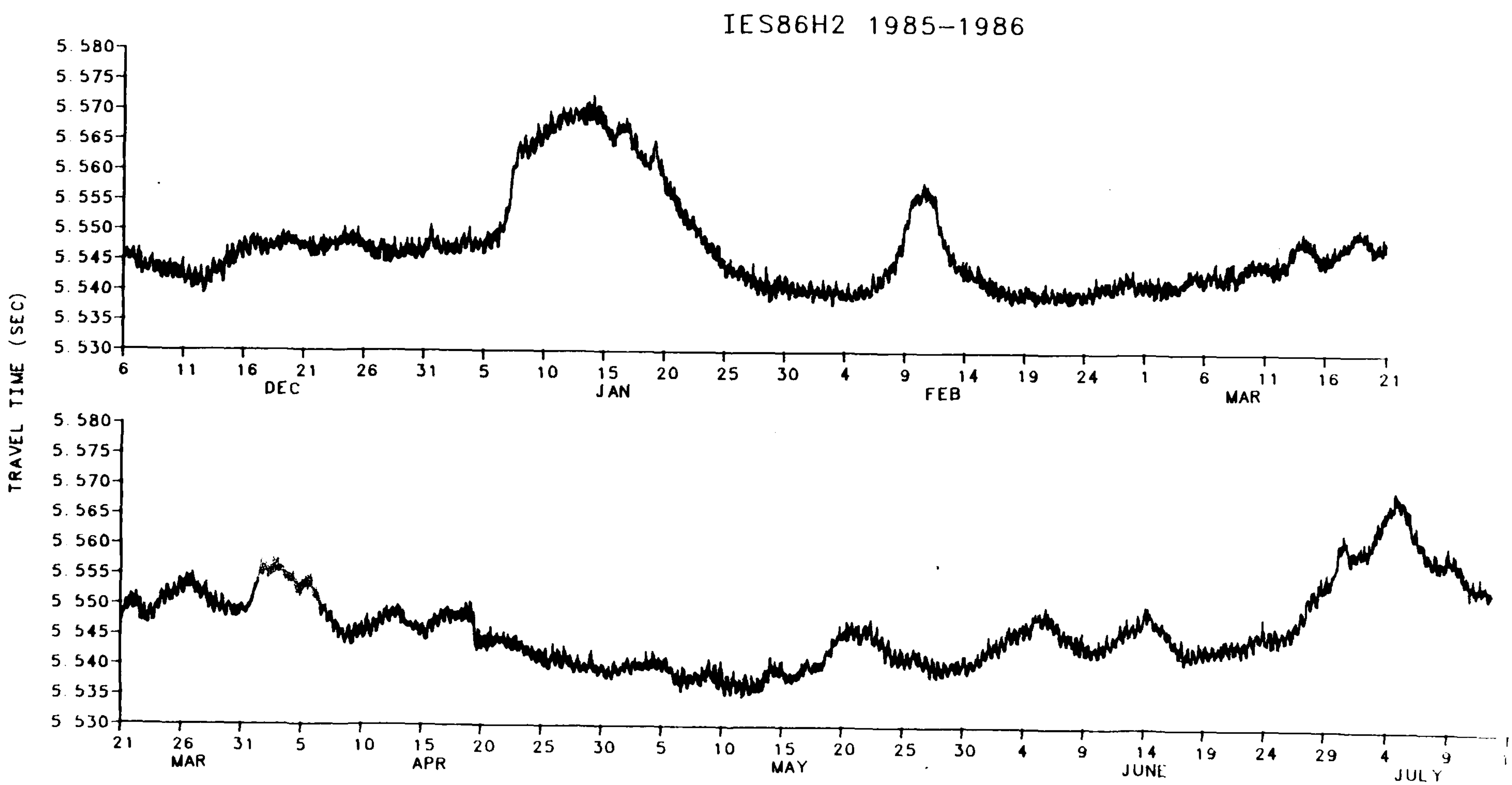

IES86H2 1985–1986
TRAVEL TIME (SEC)
5.580
5.575
5.570
5.565
5.560
5.555
5.550
5.545
5.540
5.535
5.530
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29 4 9 14
MAR
APR
MAY
JUNE
JULY

Figure 3.9

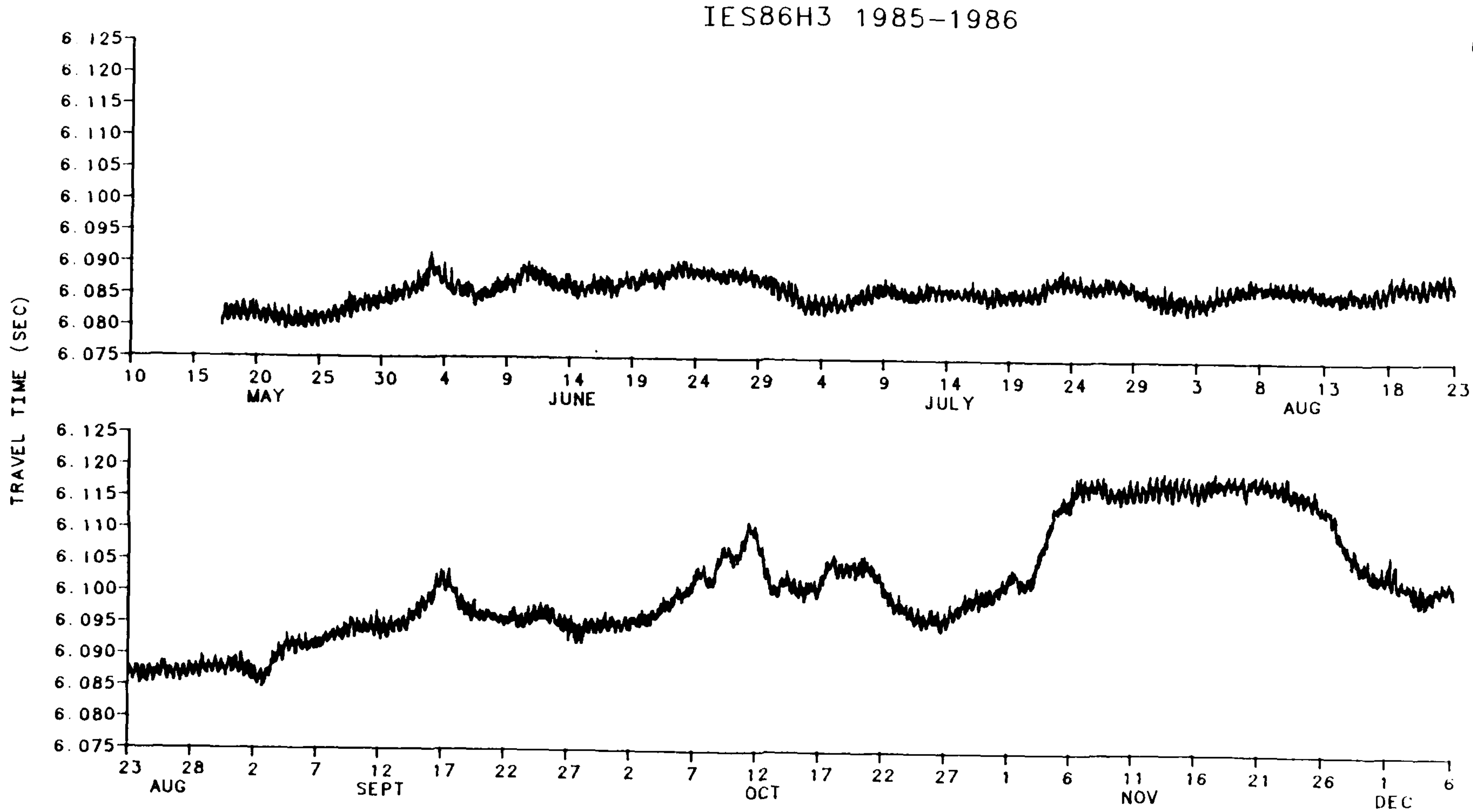
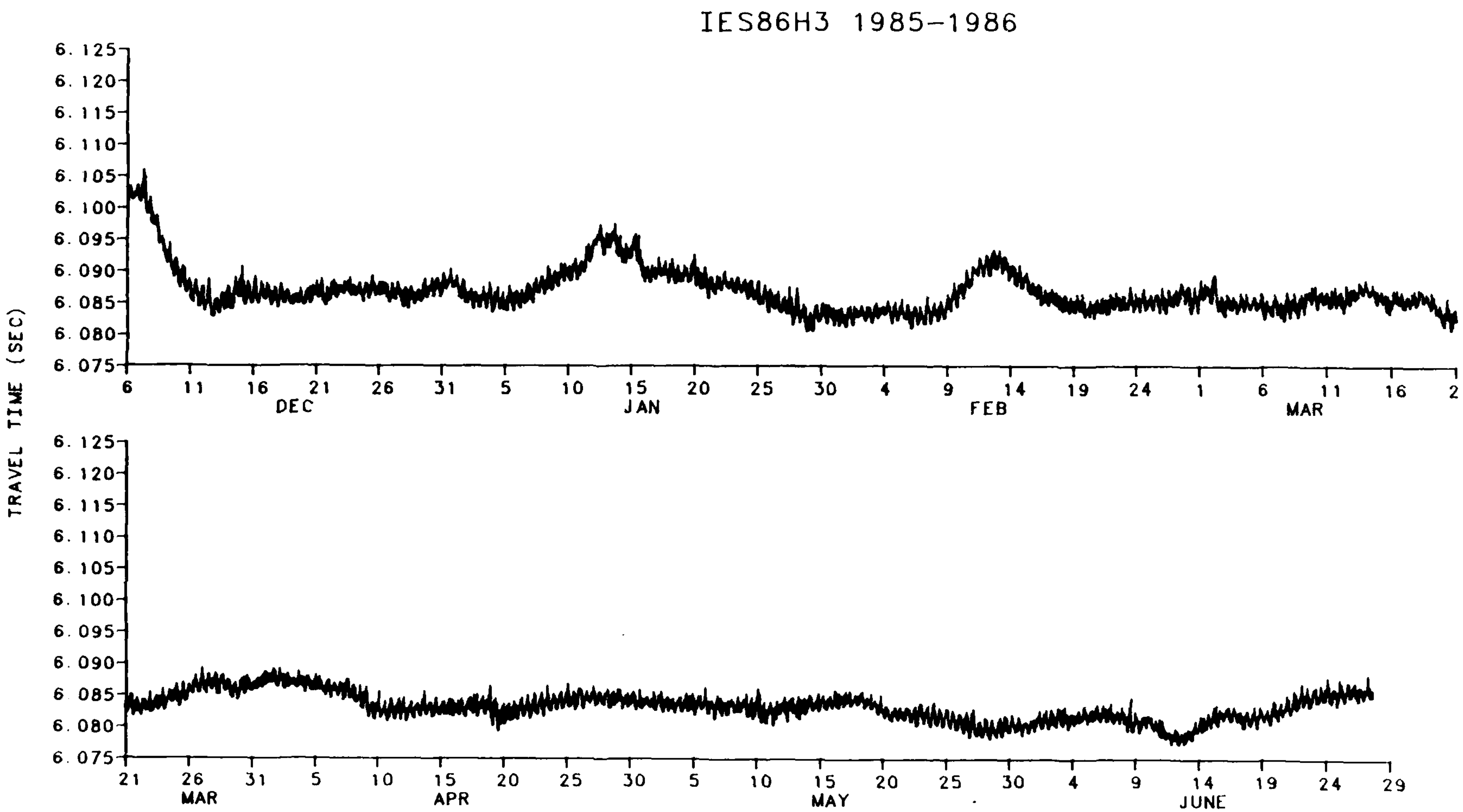


Figure 3.10 Half-hourly travel time data from IES86H3



IES86H3 1985-1986
TRAVEL TIME (SEC)
6.125
6.120
6.115
6.110
6.105
6.100
6.095
6.090
6.085
6.080
6.075
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29
MAR
APR
MAY
JUNE

Figure 3.10

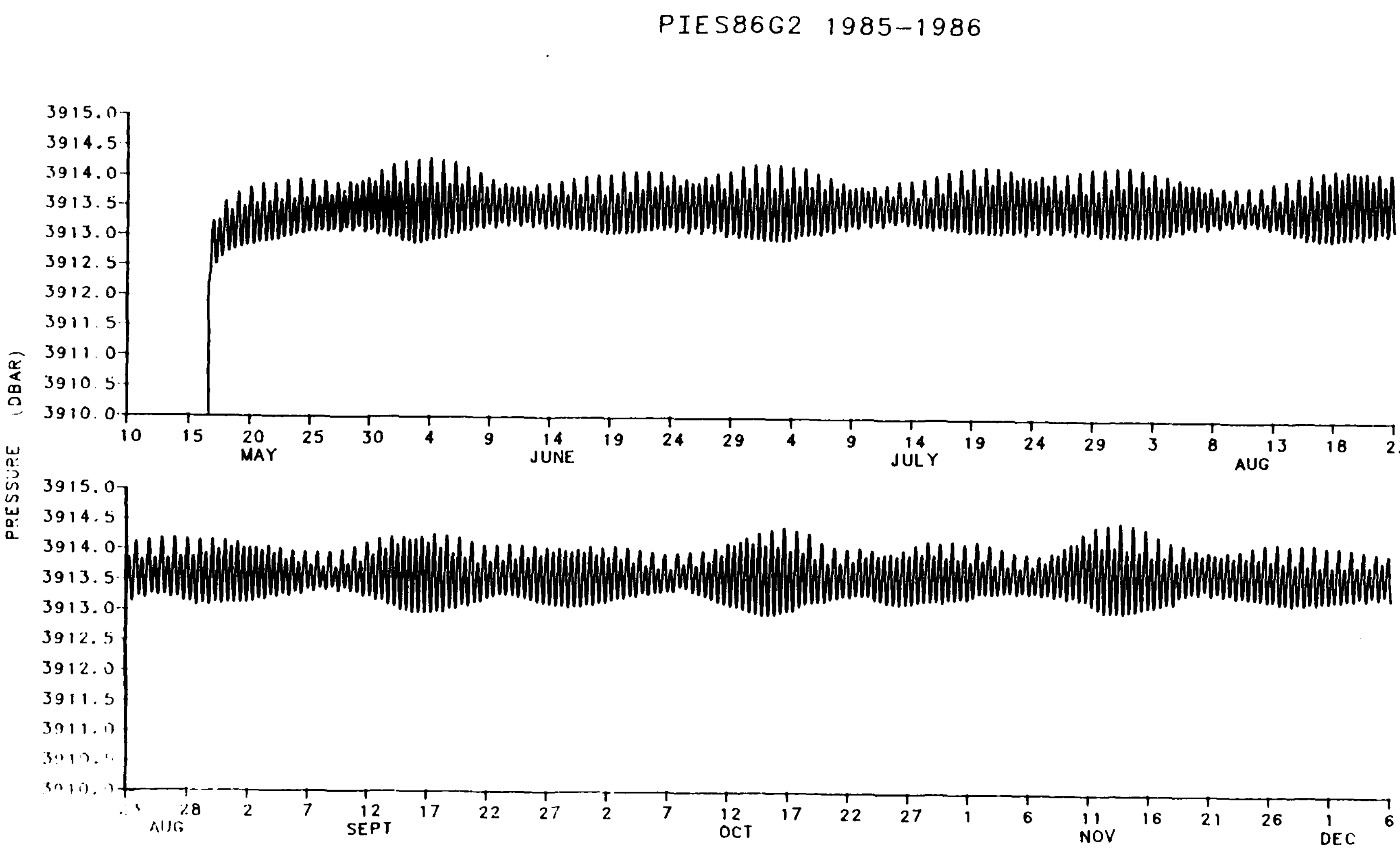


Figure 4.1 Half-hourly measured bottom pressure data from PIES86G2

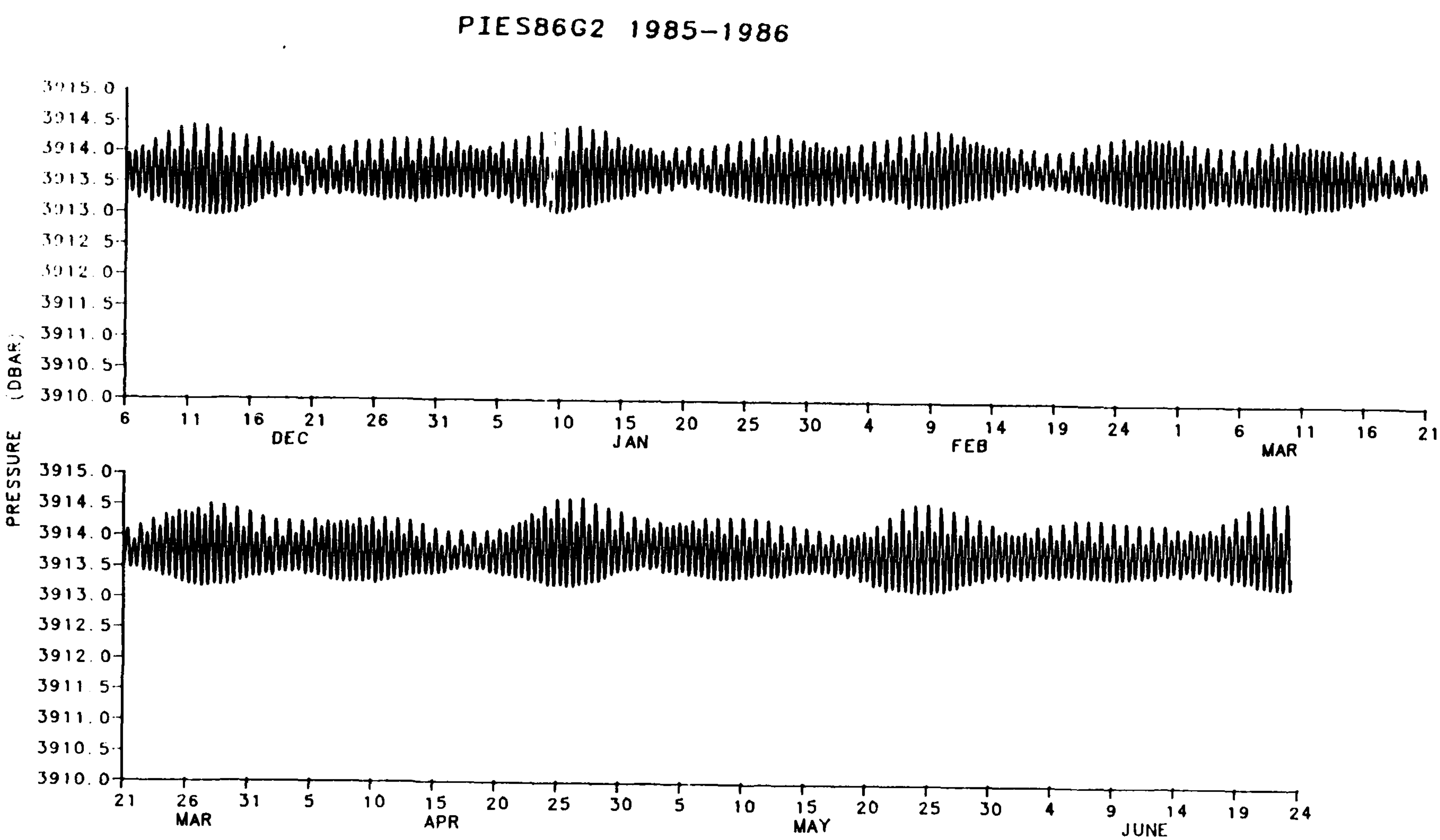

PIES86G2 1985–1986
PRESSURE (DBAR)
3915.0
3914.5
3914.0
3913.5
3913.0
3912.5
3912.0
3911.5
3911.0
3910.5
3910.0
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 4.1

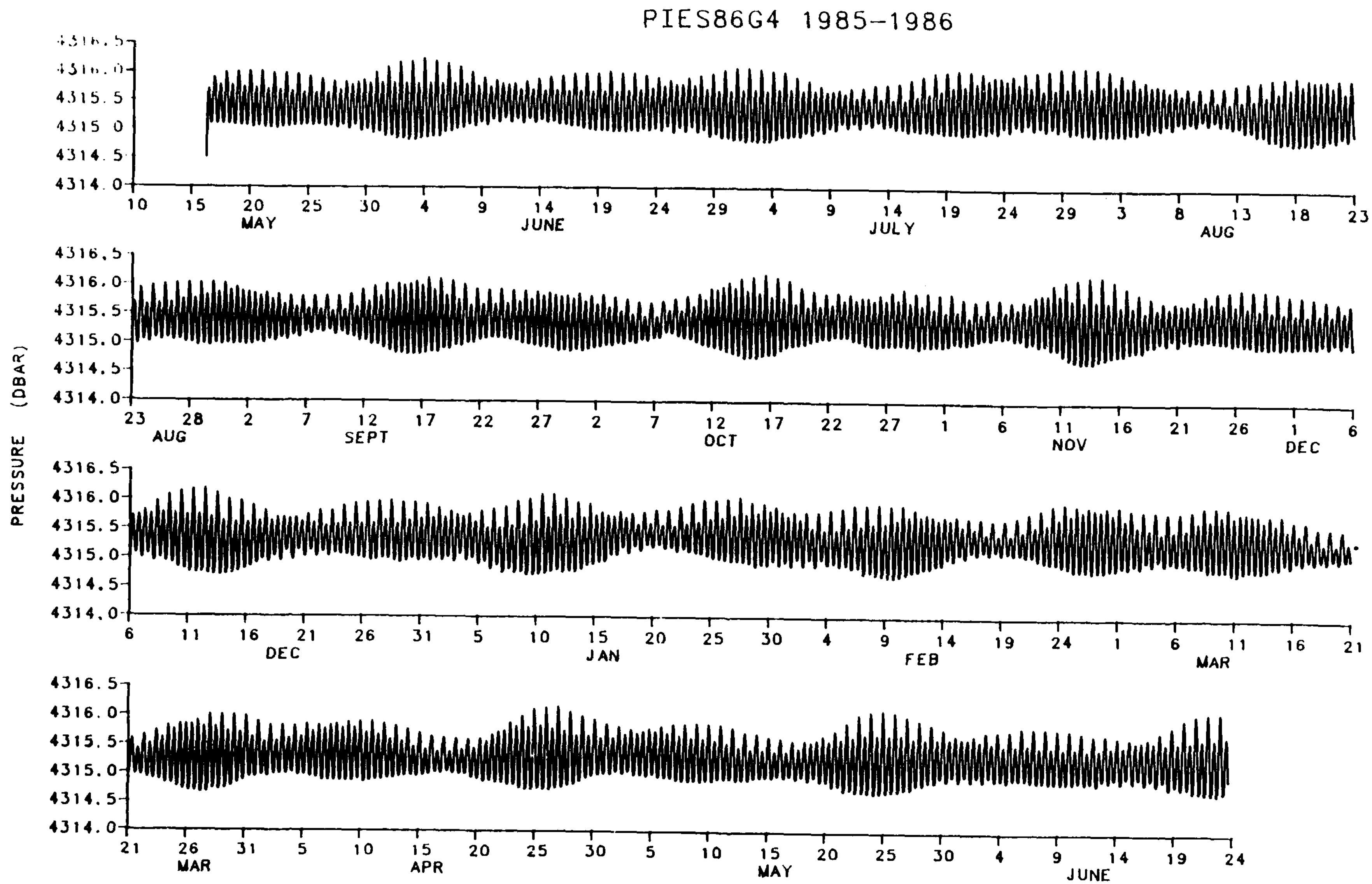


Figure 4.2 Half-hourly measured bottom pressure data from PIES86G4

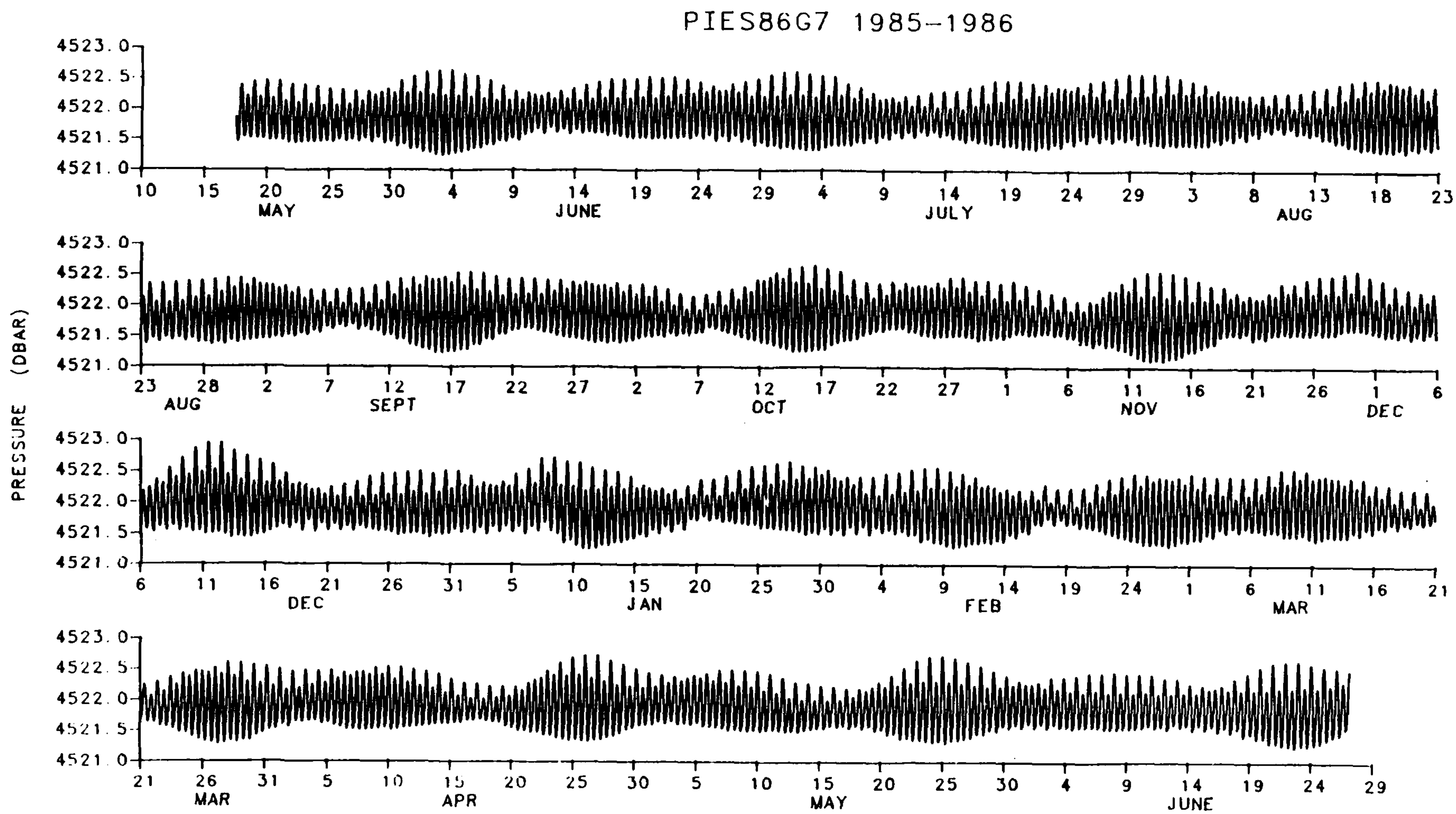


Figure 4.3 **Half-hourly measured bottom pressure data from PIES86G7**

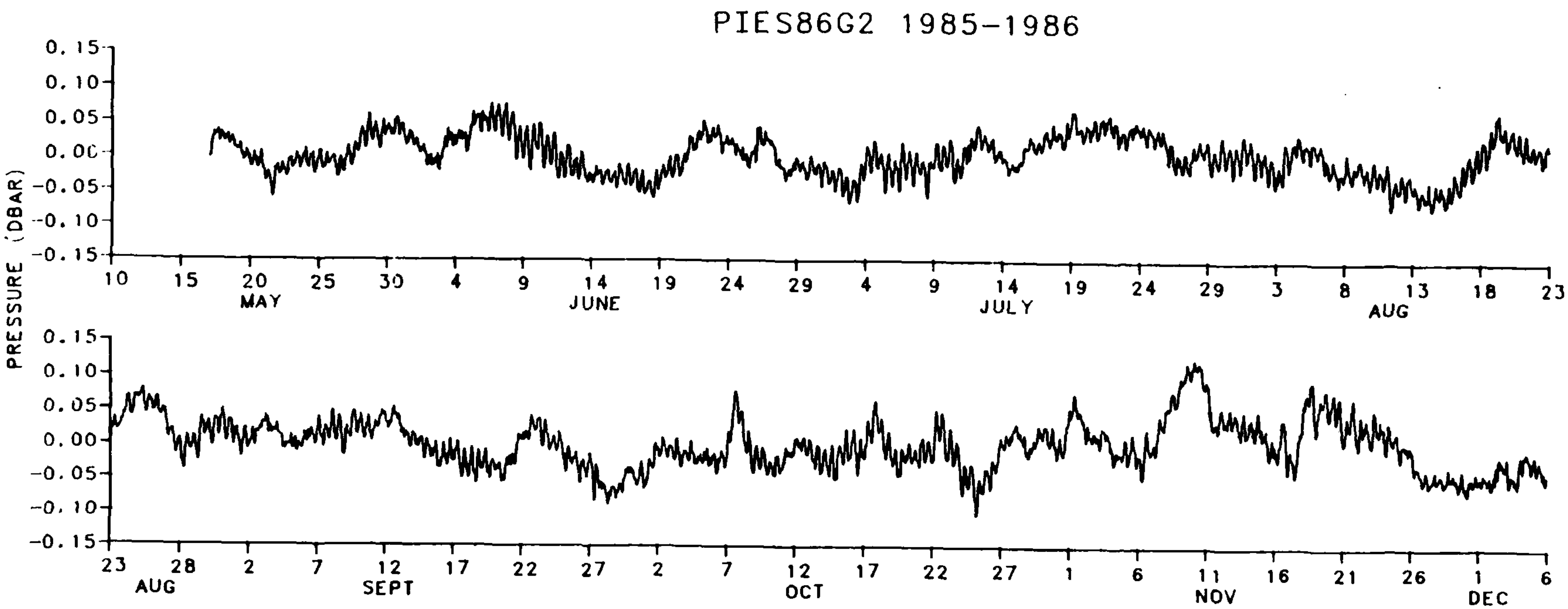


Figure 5.1 **Half-hourly residual bottom pressure data from PIES86G2**

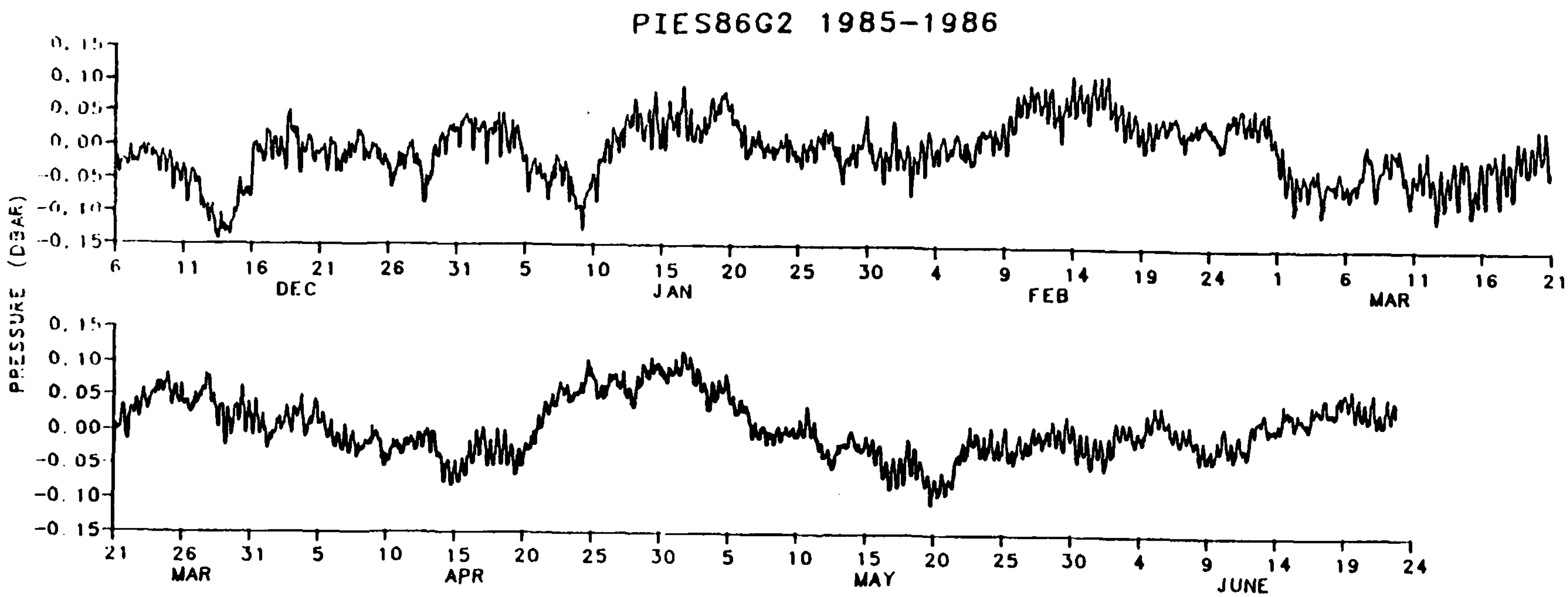

PIES86G2 1985–1986
PRESSURE (DBAR)
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 5.1

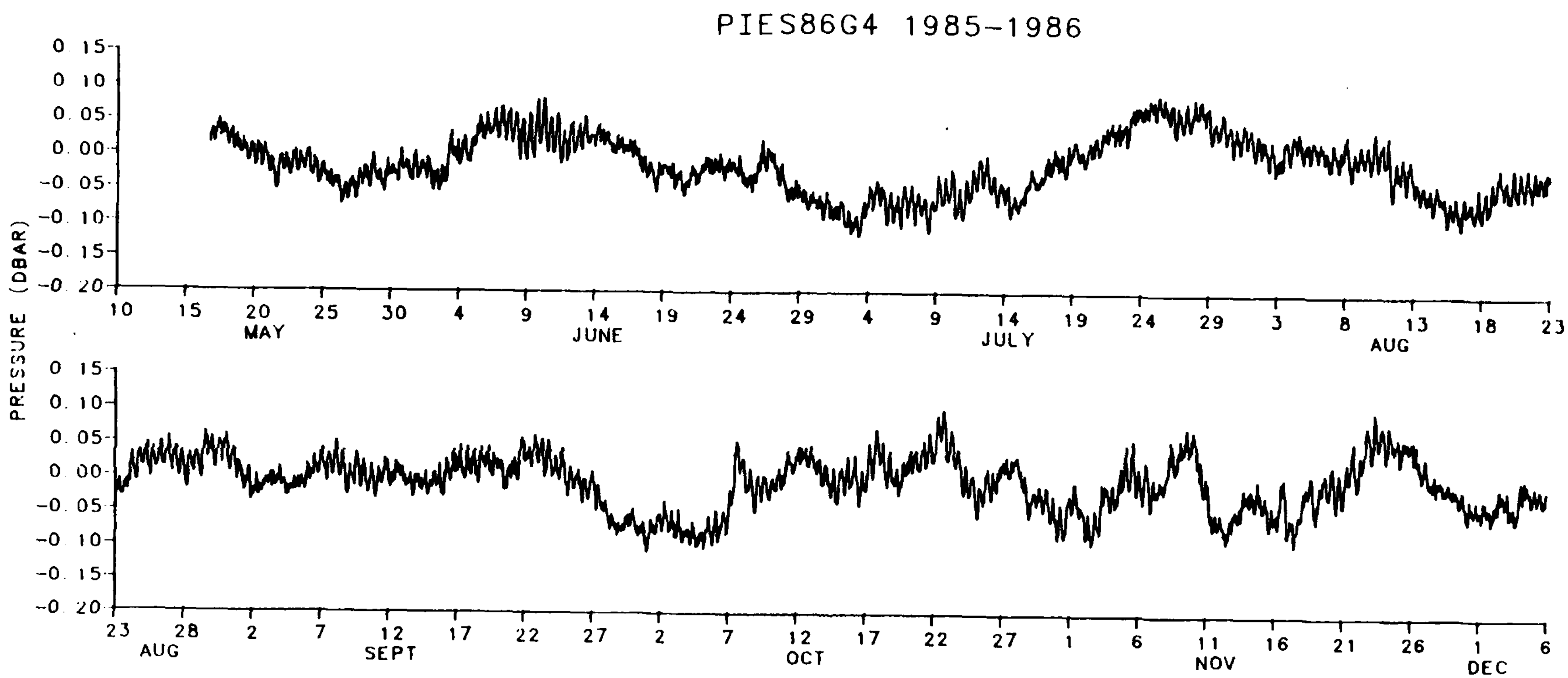


Figure 5.2 **Half-hourly residual bottom pressure data from PIES86G4**

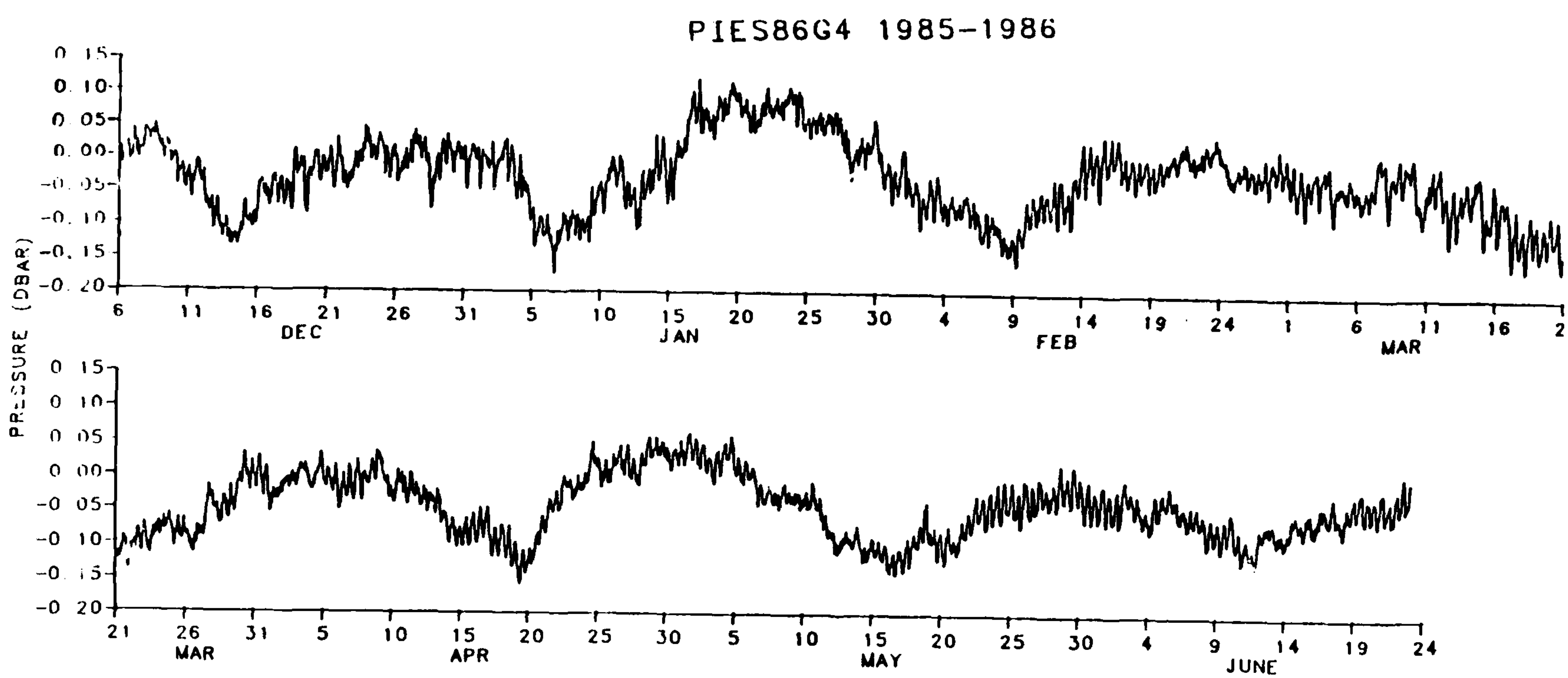

PIES86G4 1985-1986
PRESSURE (DBAR)
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 5.2

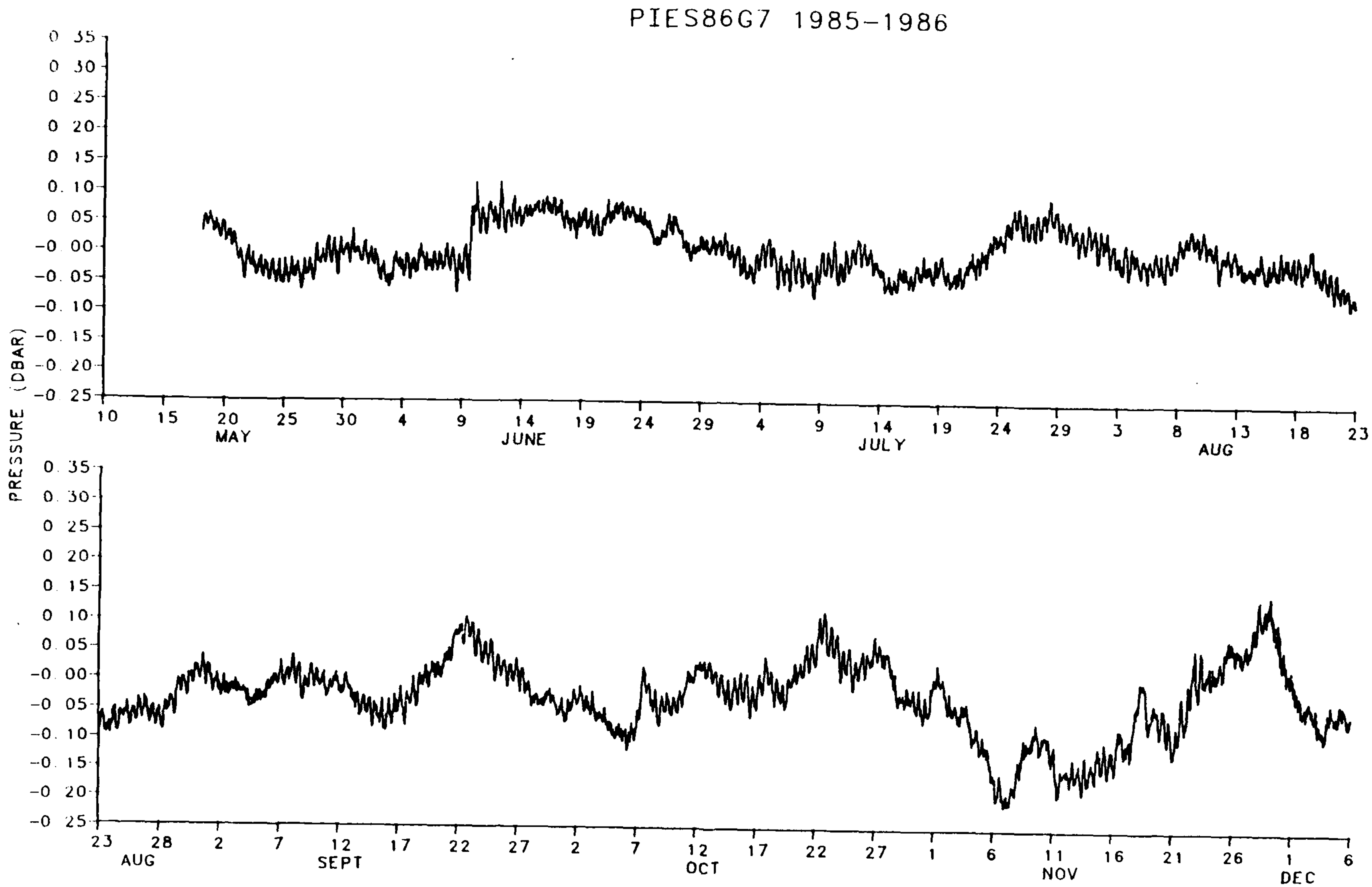


Figure 5.3 Half-hourly residual bottom pressure data from PIES86G7

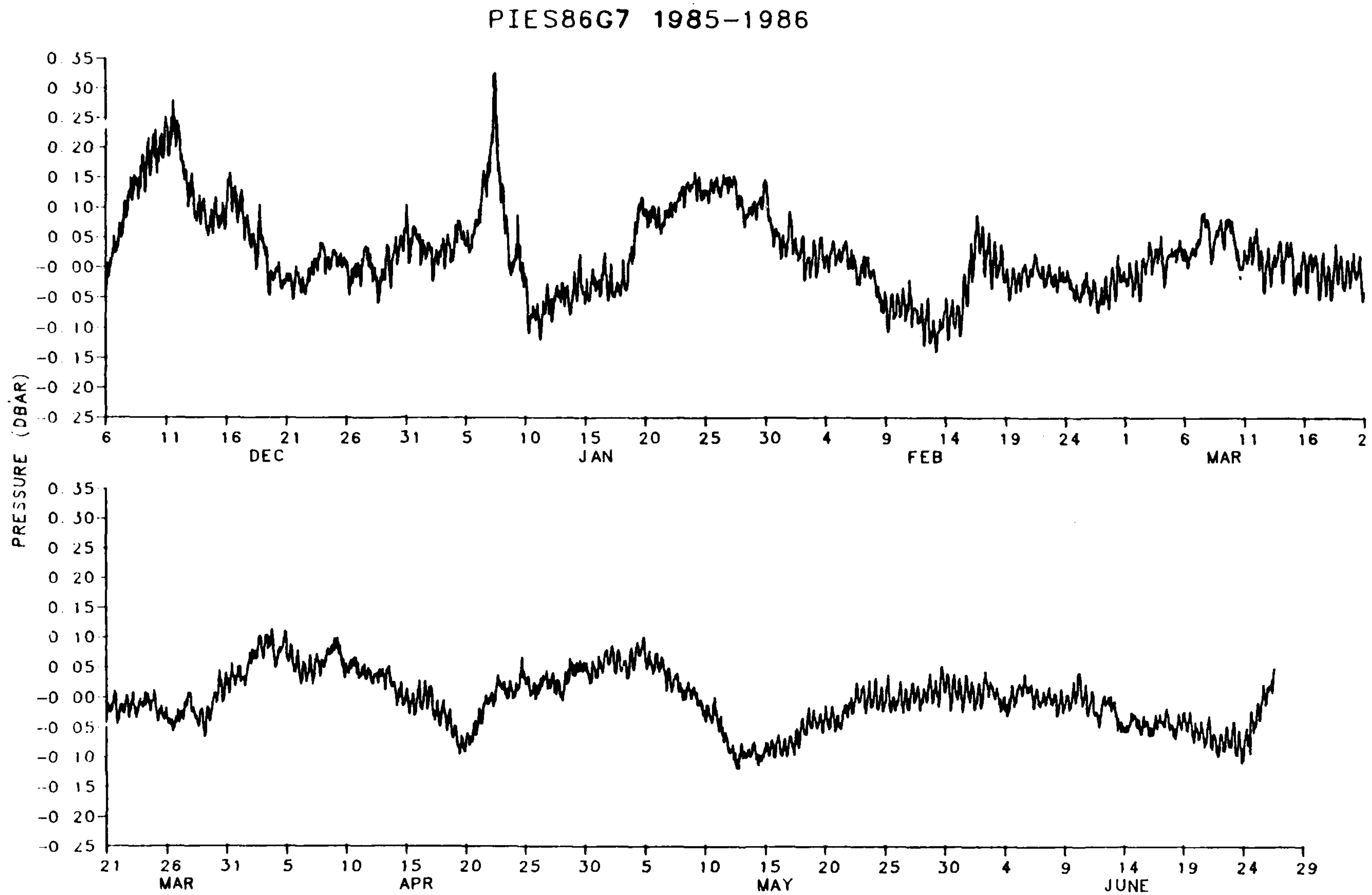

PIES86G7 1985–1986
PRESSURE (DBAR)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
-0.20
-0.25
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29
MAR
APR
MAY
JUNE

Figure 5.3

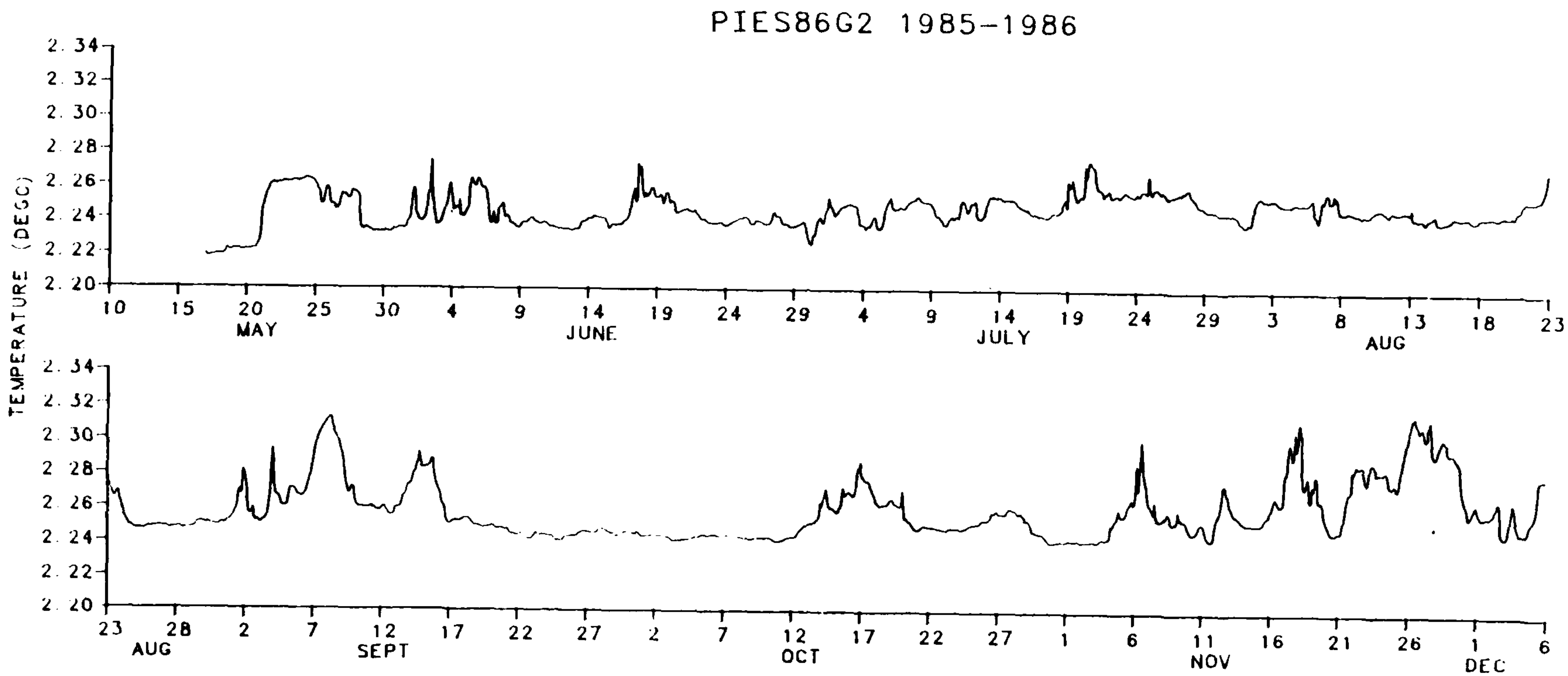


Figure 6.1 Half-hourly temperature data from PIES86G2

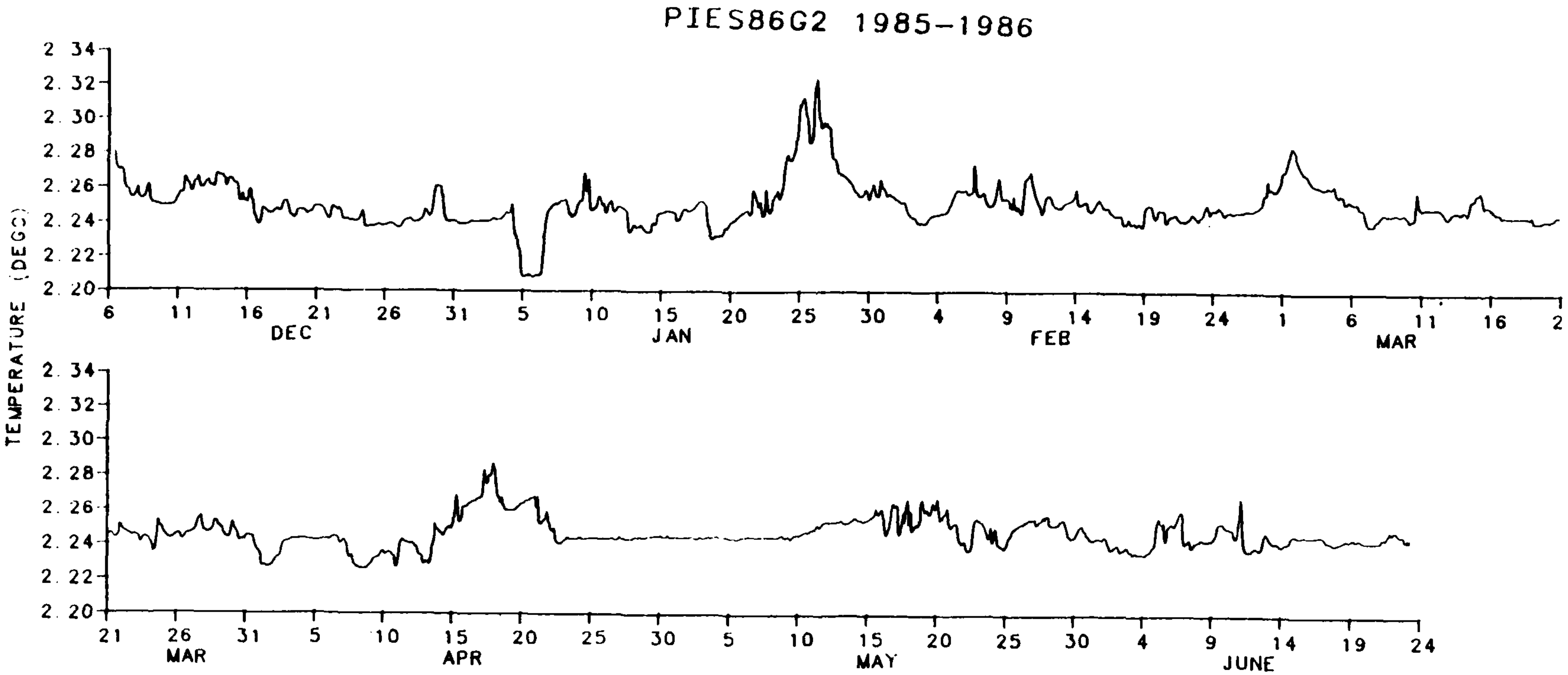

PIES86G2 1985-1986
TEMPERATURE (DEGC)
2.34
2.32
2.30
2.28
2.26
2.24
2.22
2.20
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 6.1

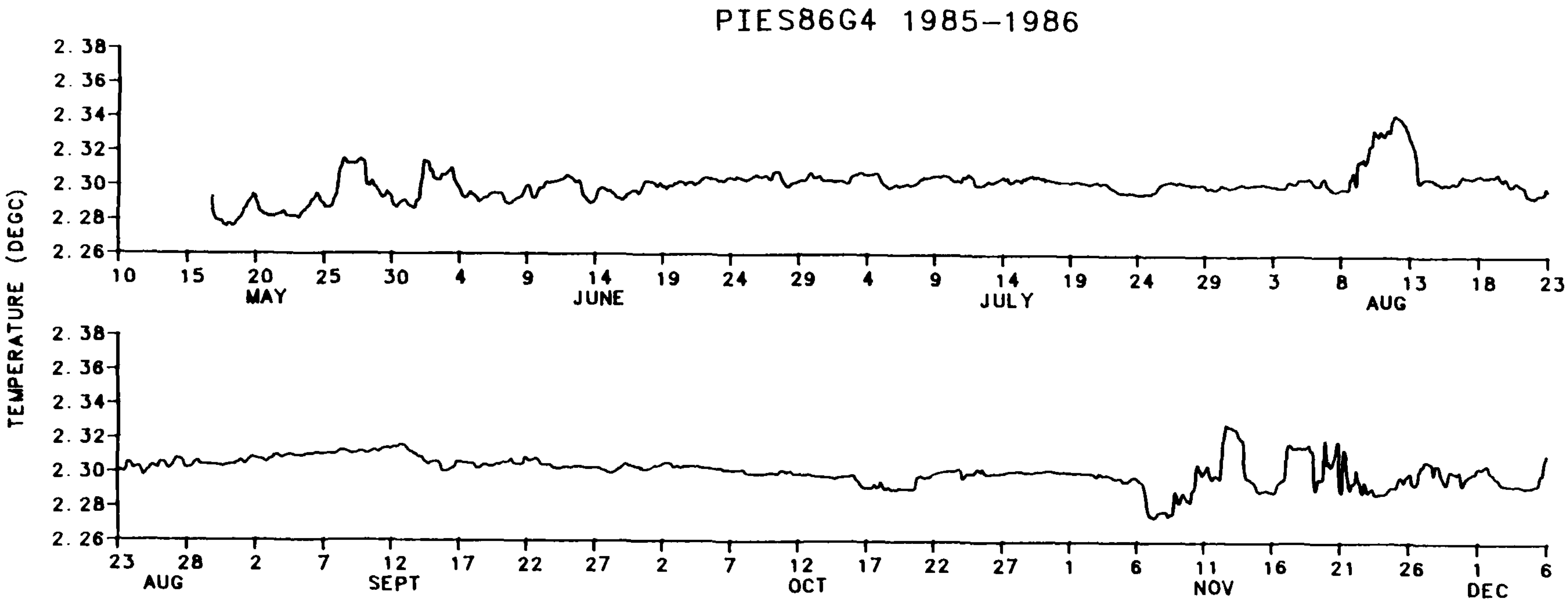


Figure 6.2 Half-hourly tempe...ure data from PIES86G4

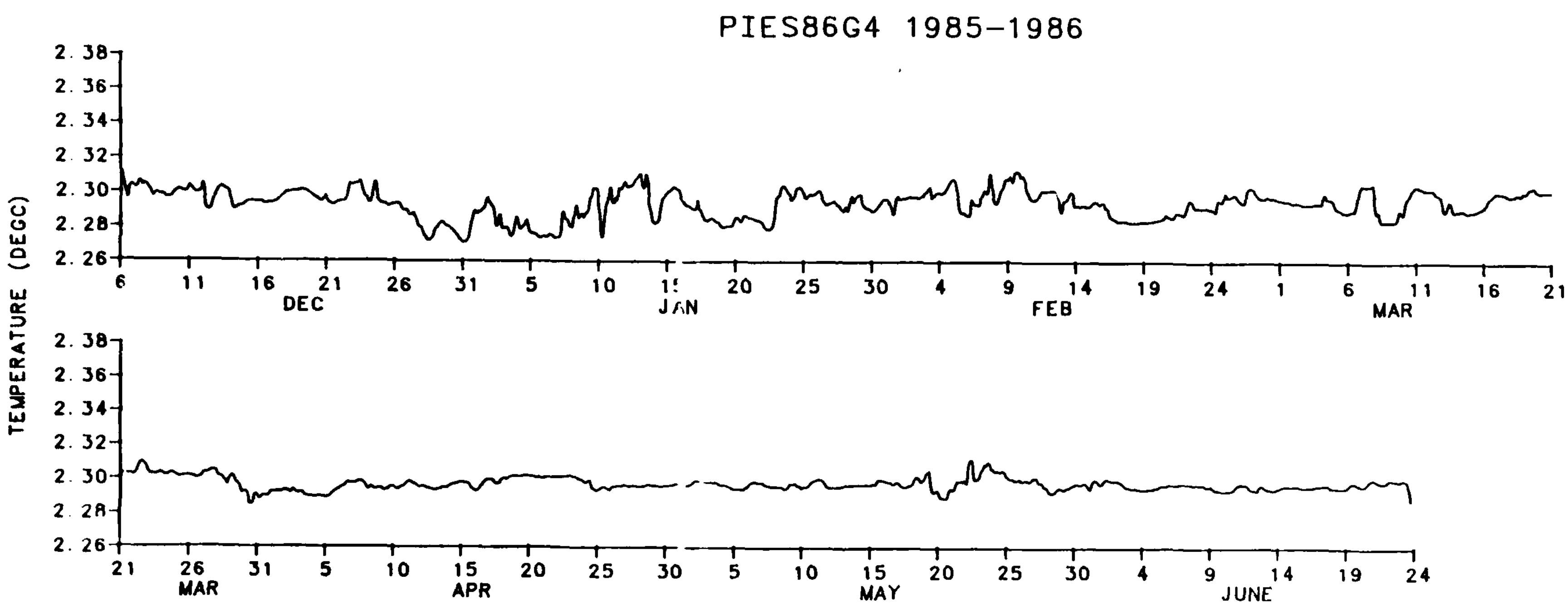

PIES86G4 1985-1986
TEMPERATURE (DEGC)
2.38
2.36
2.34
2.32
2.30
2.28
2.26
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24
MAR
APR
MAY
JUNE

Figure 6.2

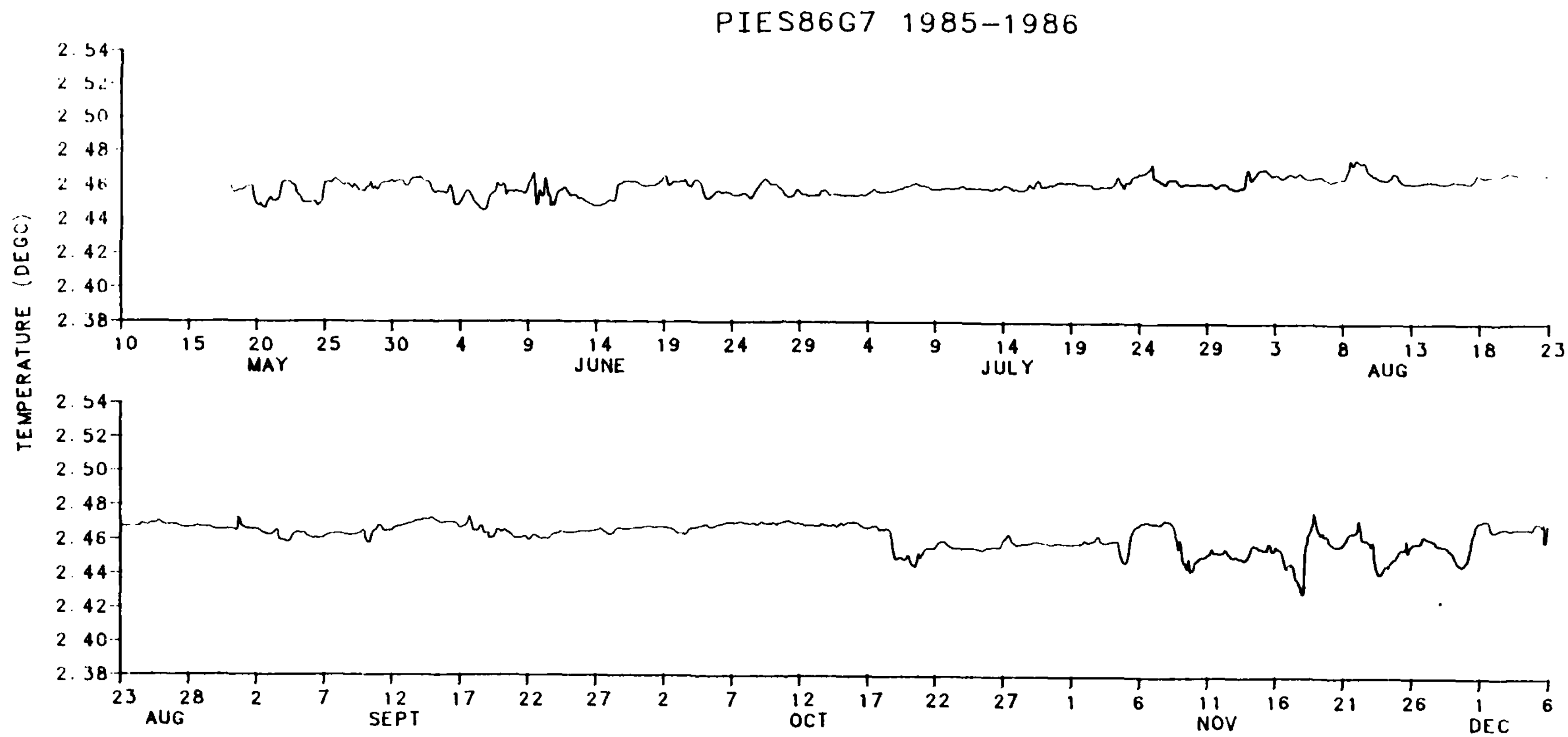


Figure 6.3 Half-hourly temperature data from PIES86G7

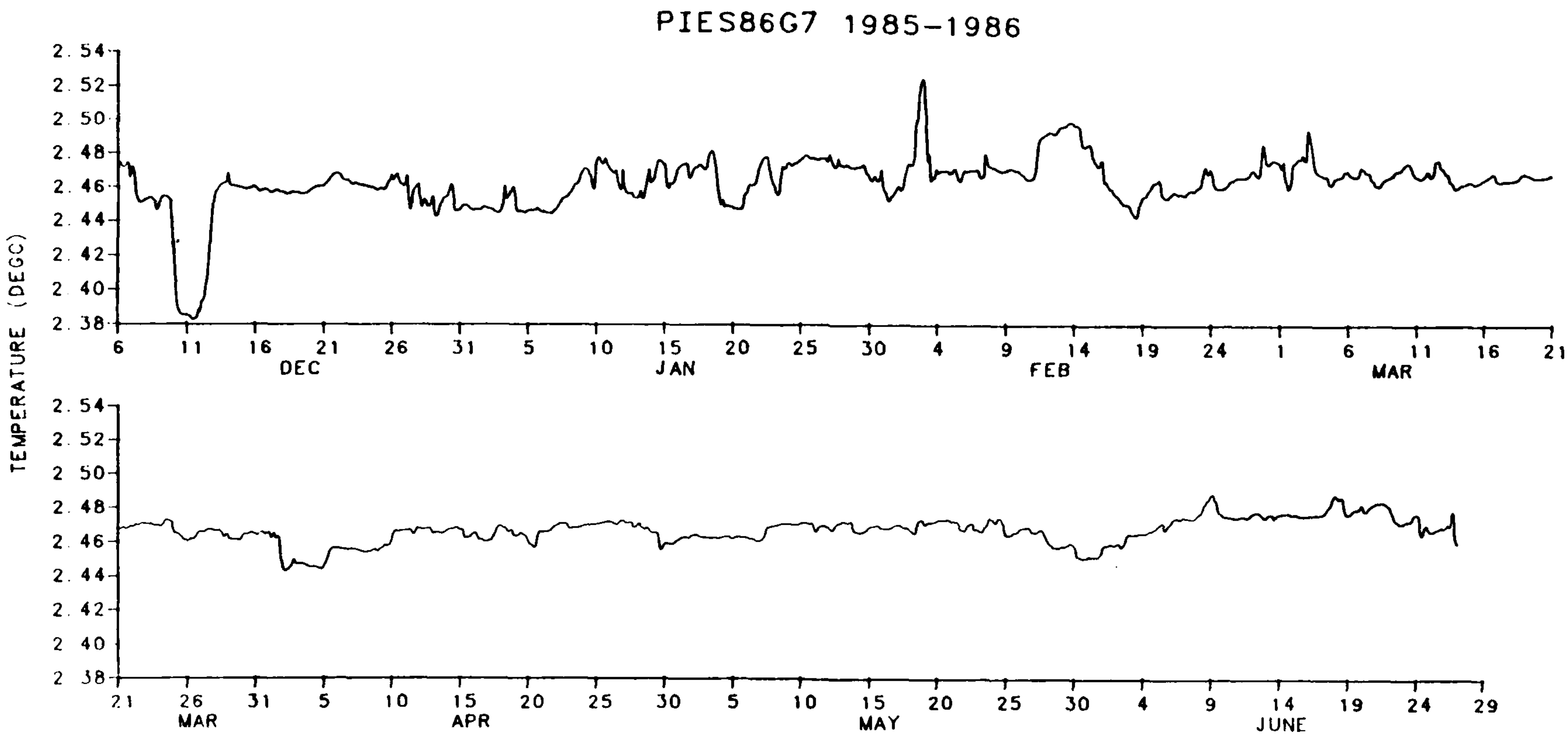

PIES86G7 1985-1986
TEMPERATURE (DEGC)
2.54
2.52
2.50
2.48
2.46
2.44
2.42
2.40
2.38
6 11 16 21 26 31 5 10 15 20 25 30 4 9 14 19 24 1 6 11 16 21
DEC
JAN
FEB
MAR
21 26 31 5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29
MAR
APR
MAY
JUNE

Figure 6.3

SECTION 4

40 HRLP Data For Each Cross-Stream Line

The 40 HRLP thermocline depths (Z_{12}), bottom pressure, and temperature records are presented for each instrument. These are grouped by cross-stream line, with the northernmost IES of each line plotted at the top of the figure. Each plot is labelled with the instrument name in the upper left corner.

The 40 HRLP Z_{12} records for each cross-stream section are presented first. These are followed by the 40 HRLP residual pressure records and the 40 HRLP temperature data for the three instruments which had the additional pressure and temperature sensors.

The time scale is the same for all plots, with each increment corresponding to 10 days. The axis begins on 0000 GMT of the first date labelled.

The vertical scale is consistent between instruments, with each increment corresponds to 100 m for the Z_{12} records, 0.05 dbar for bottom pressure measurements, and 0.04°C for the temperatures.

The sampling interval is 6 hours for all low-passed data records. The length and the start and end times of the data records are tabulated in Section 2.

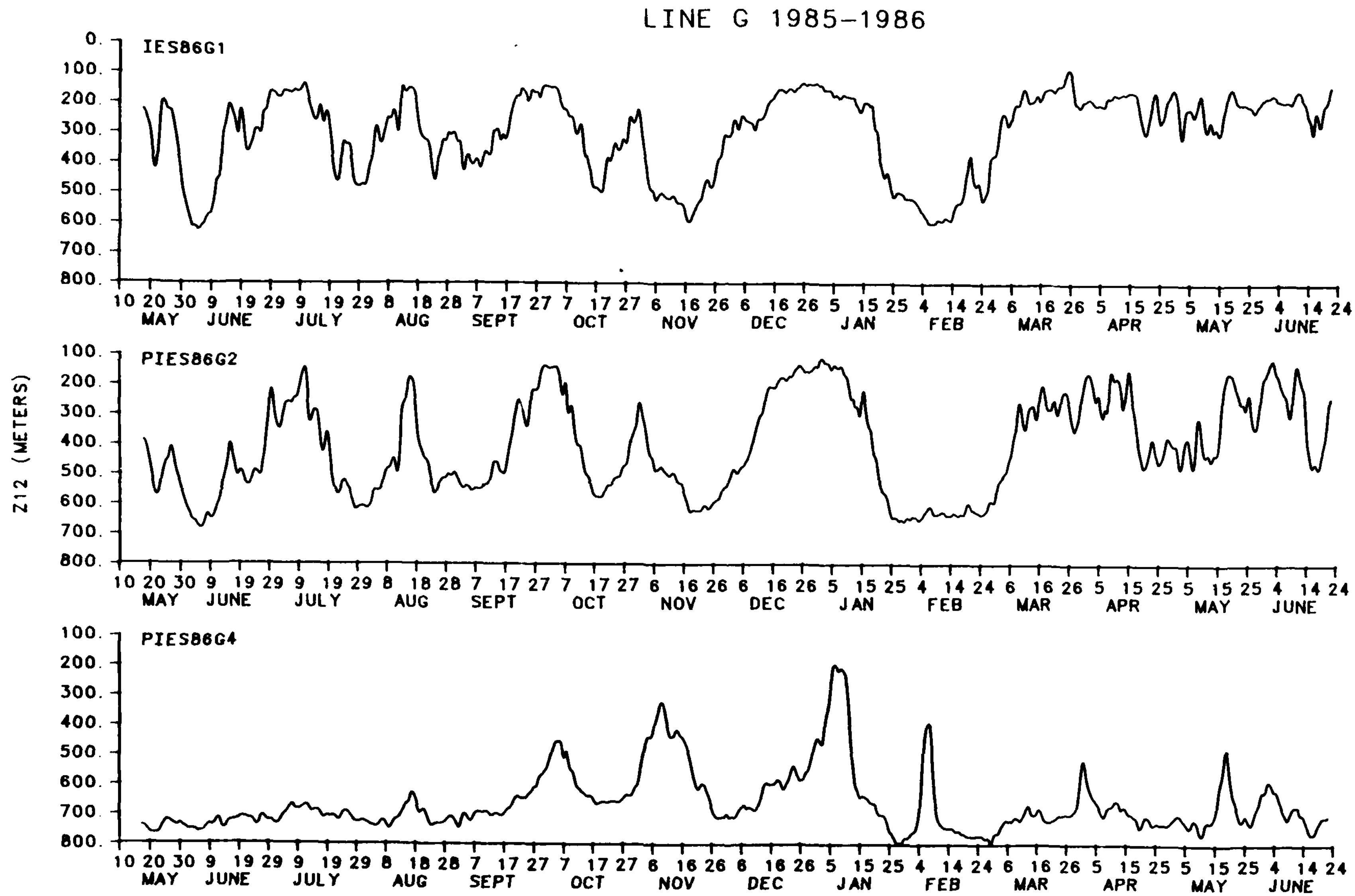


Figure 7.1 40 HRLP thermocline depth data from IES86G1, PIES86G2, PIES86G4, IES86G5, IES86G6, PIES86G7 and IES86G8 along line G

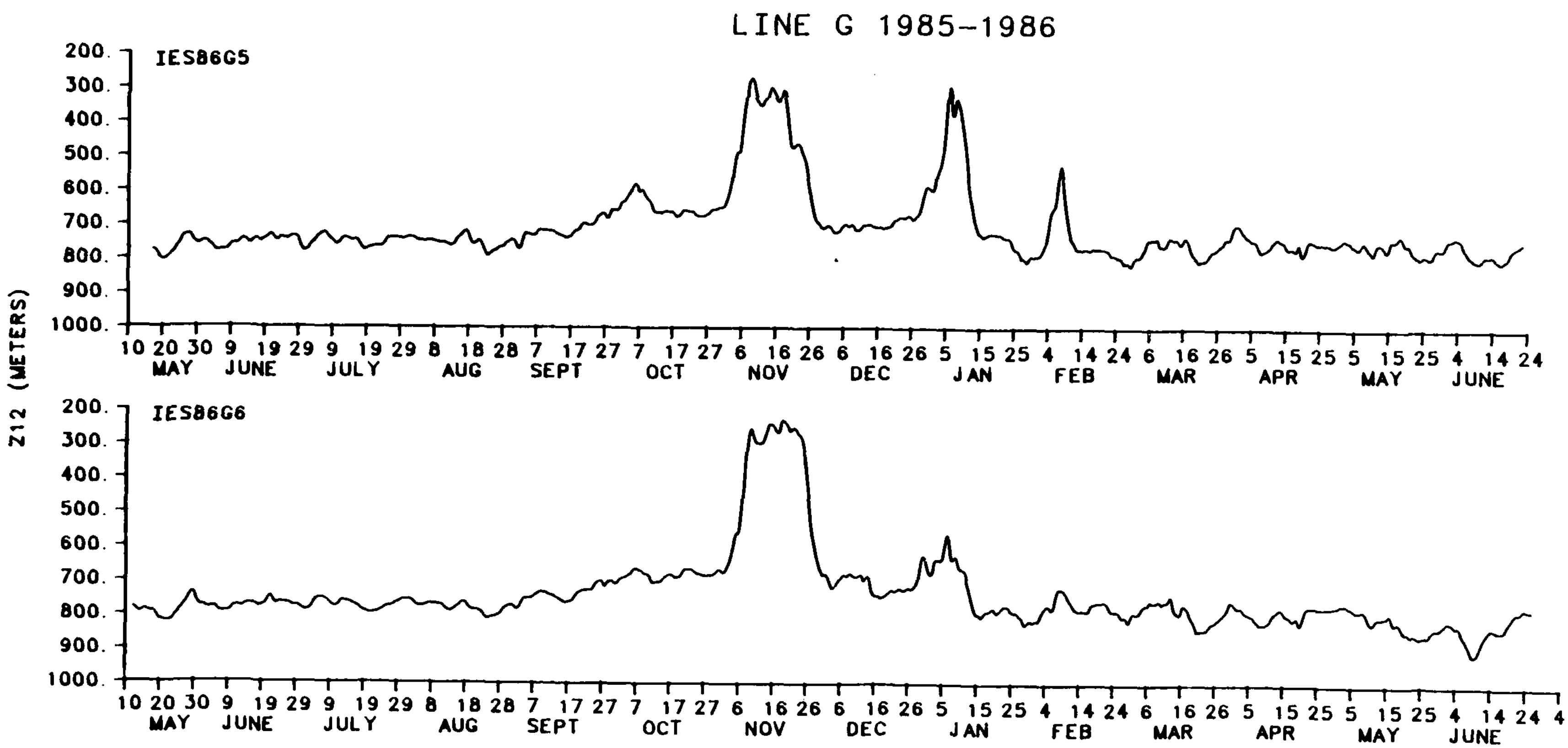

LINE G 1985-1986
IES86G5
IES86G6
Z12 (METERS)
200.
300.
400.
500.
600.
700.
800.
900.
1000.
10 20 30 9 19 29 9 19 29 8 18 28 7 17 27 7 17 27 6 16 26 6 16 26 5 15 25 4 14 24 6 16 26 5 15 25 5 15 25 4 14 24 4
MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE

Figure 7.1

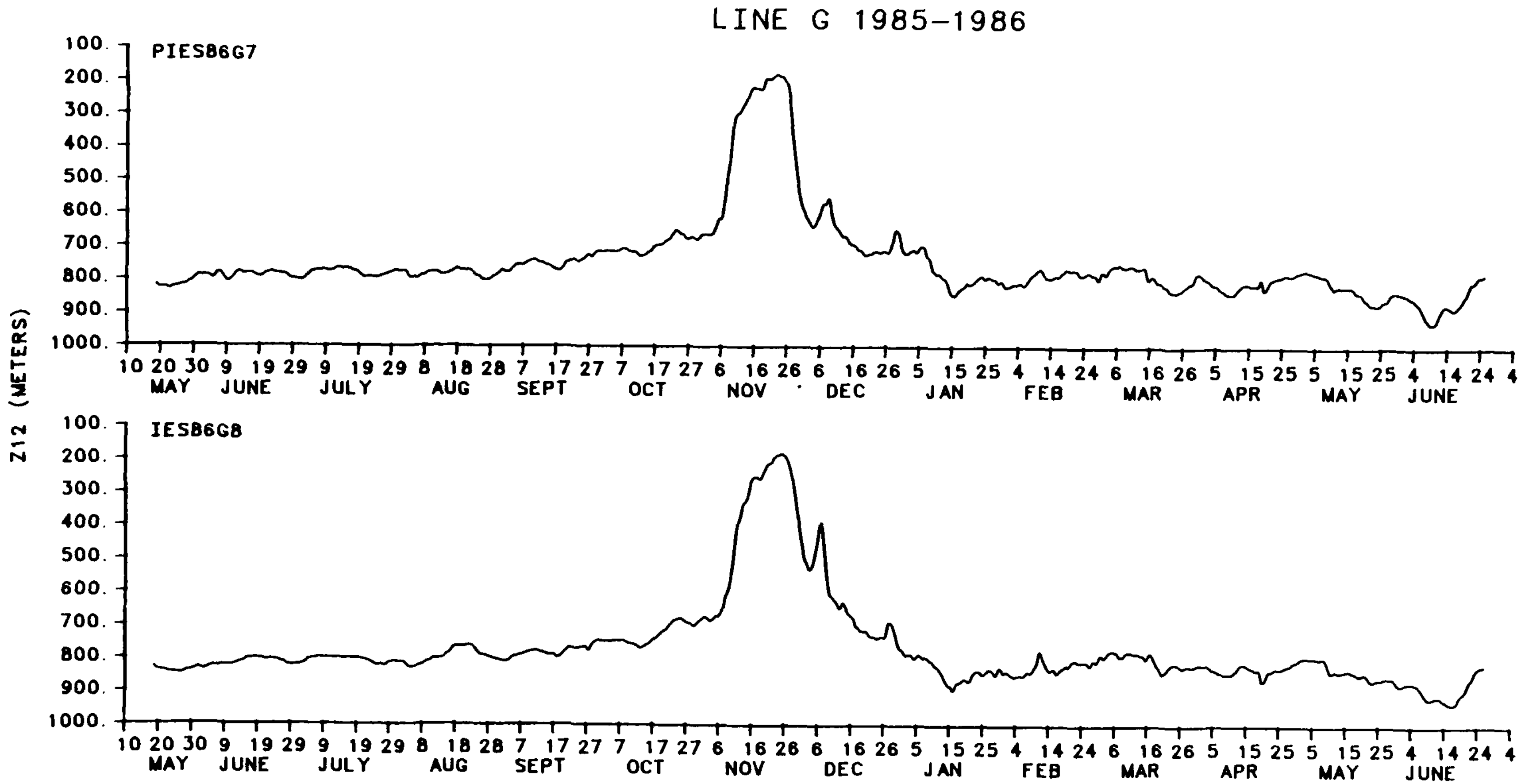

LINE G 1985–1986
PIES86G7
IES86G8
Z12 (METERS)
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
10 20 30 9 19 29 9 19 29 8 18 28 7 17 27 7 17 27 6 16 26 6 16 26 5 15 25 4 14 24 6 16 26 5 15 25 5 15 25 4 14 24 4
MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE

Figure 7.1

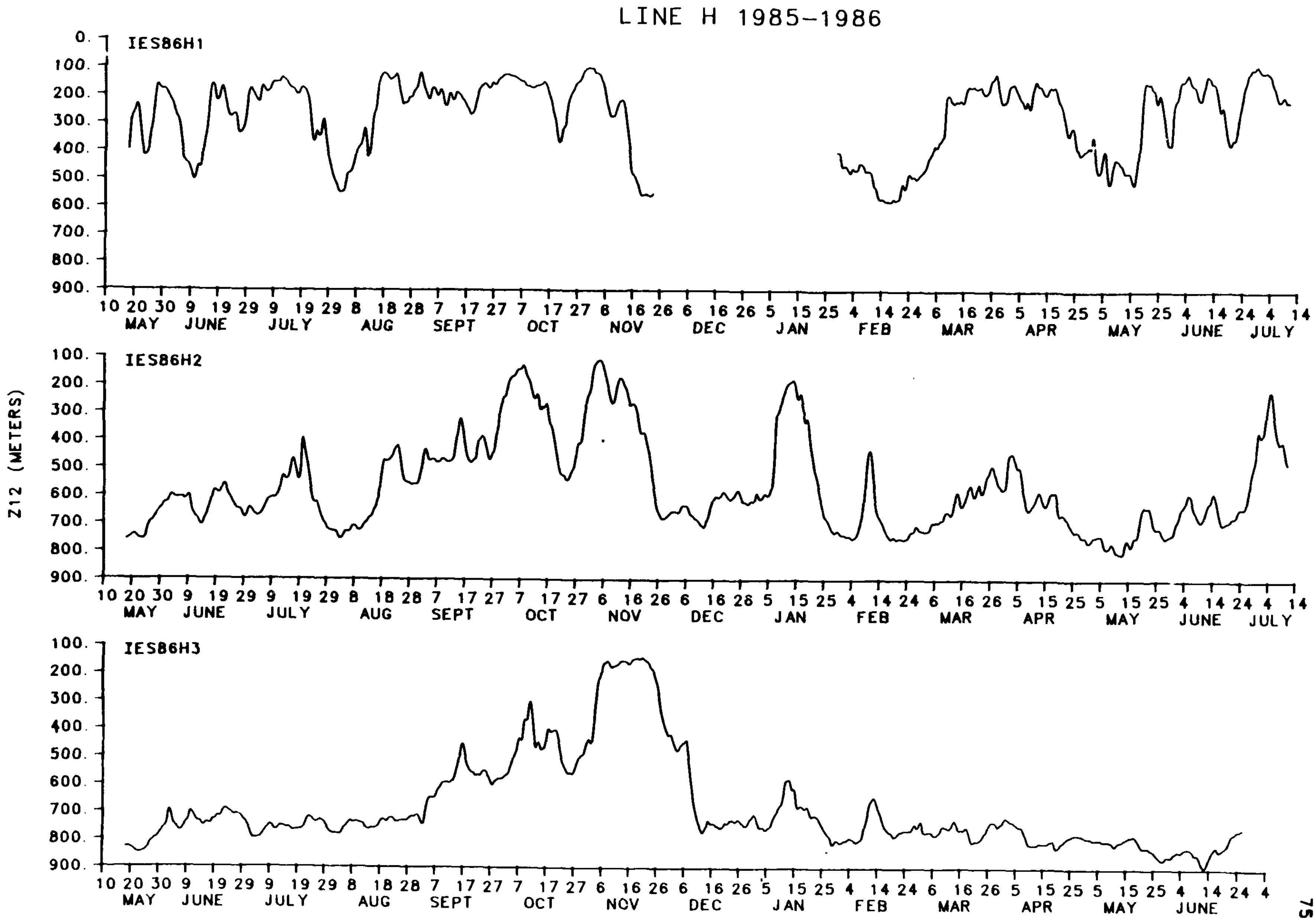


Figure 7.2 40 HRLP thermocline depth data from IES86H1, IES86H2, and IES86H3 along line H

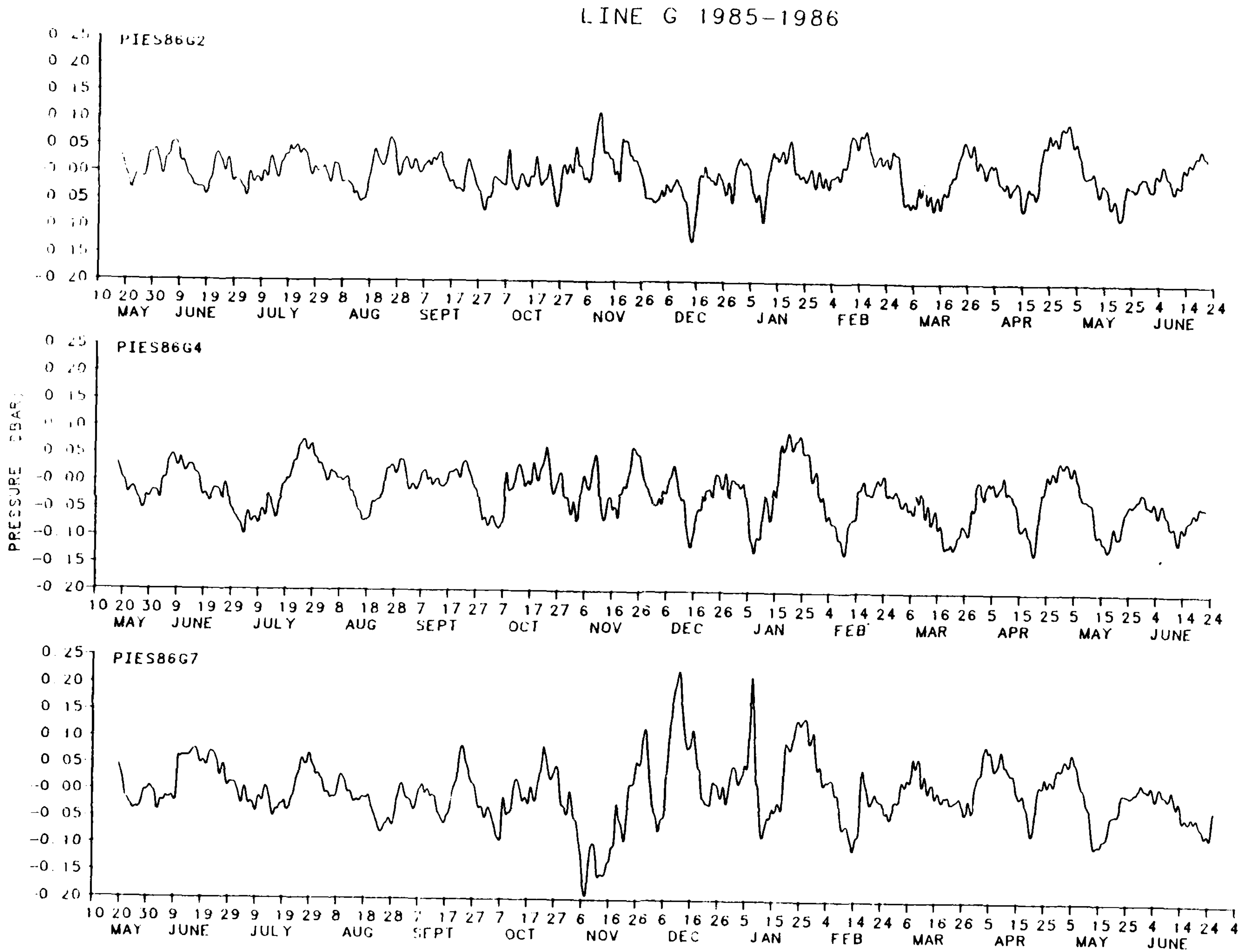


Figure 8. 40 HRLP bottom pressure data from PIES86G2, PIES86G4, and PIES86G7 along line G

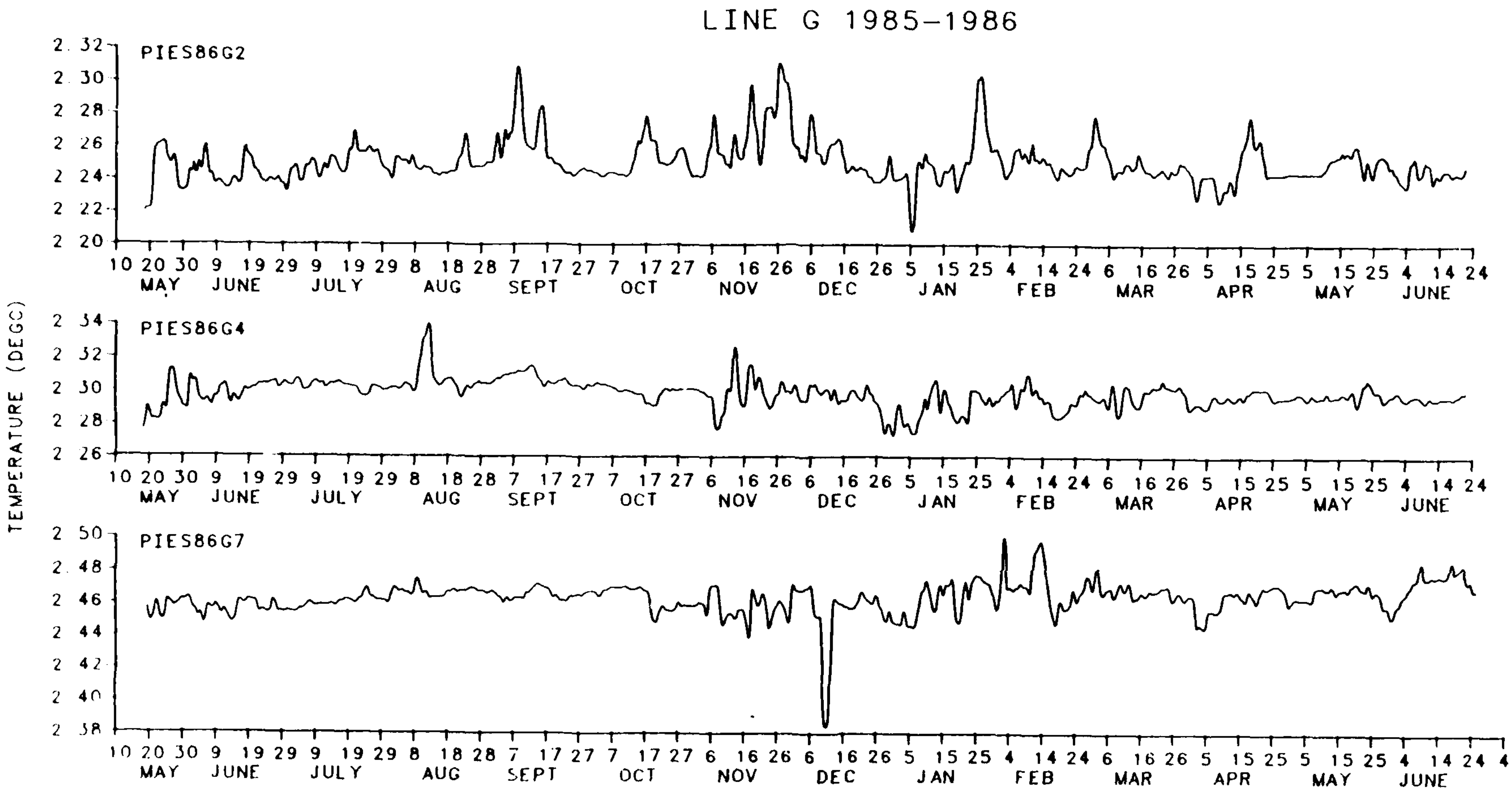


Figure 9. 40 HRLP temperature data from PIES86G2, PIES86G4, and PIES86G7 along line G

SECTION 5

Thermocline Depth Mapping

5.1 Objective Analysis Techniques

Objective maps of the thermocline (Z_{12}) field in the boxed array region shown in Figure 1 have been produced at daily intervals from the low-passed Z_{12} records. The objective mapping techniques were developed by E. Carter (1983) and special adaptations for their application to the Gulf Stream frontal zone are discussed in Watts and Tracey (1985). Two results presented in this latter work are of particular importance to the objective mapping performed here: 1) If the mean field is removed, the perturbations have essentially isotropic correlation fields. 2) The space-time correlation functions used for the objective analysis are shown in Watts and Tracey (1985).

The objective analysis is performed on the "perturbation fields", which are obtained by removing the mean field from the input data set and then normalizing by the standard deviation. To represent the mean field, $\overline{Z_{12}(x,y)}$, a third order polynomial was fitted to the mean values observed during the May 1985 to June 1986 deployment period. The function form of the polynomial was:

$$\begin{aligned}\overline{Z_{12}(x,y)} &= B_0 + B_1 x + B_2 y + B_{11} x^2 + B_{12} xy + B_{22} y^2 \\ &\quad + B_{111} x^3 + B_{112} x^2 y + B_{122} x y^2 + B_{222} y^3,\end{aligned}$$

where (x, y) is the position in kilometers from the origin at 36°00'N, 73°50'W, B_0 is $-0.1081394\text{E}+03$, B_1 is $0.8574518\text{E}+01$, B_2 is $0.3523002\text{E}+01$, B_{11} is $-0.2627621\text{E}-01$, B_{12} is $-0.3183994\text{E}-01$, B_{22} is $-0.3107261\text{E}-01$, B_{111} is $0.2203297\text{E}-04$, B_{112} is $0.3989283\text{E}-04$, B_{122} is $0.6482679\text{E}-04$, and B_{222} is $0.2371464\text{E}-04$. The standard deviation field, $\sigma(x, y)$,

was defined as a function of the mean field depth, from a Gaussian form representative of all IES records:

$$\sigma(x,y) = A + Bexp(- [\frac{\overline{Z_{12}(x,y)} - Z_o}{C}]^2) , \quad (1)$$

where A is 50 m, B is (200 m − A), C is 200 m, Z_0 is 470 m, and $\overline{Z_{12}(x,y)}$ is the mean value at the (x,y) location. Figure 10 shows both the mean and standard deviation fields in plan view.

For each output grid point, the objective mapping technique selects, from all the input data within a specified maximum time lag (τ) and radial distance (R), the number of points (N) which have the highest correlations. The output fields in Figures 11 and 12 result from specifying N = 7, $\tau = \pm 1$ day, and R = 120 km, and using the idealized correlation function (Watts and Tracey, 1985) with an assumed noise level E = 0.05.

The output of the objective mapping is the perturbation field (not shown) on a full grid of points, with 20 km grid spacing, within the mapped region. The thermocline depth maps (Figure 12) are obtained by renormalizing the perturbation field by the standard deviation and restoring the mean. The accuracy of these output fields can be obtained from the estimated error fields, which are shown in Figure 11. A detailed discussion of the accuracy is given in Watts and Tracey (1986).

5.2 Daily Map Fields

Contour plots of the mean field, variance field, error fields, and thermocline depth (Z_{12}) fields are presented.

Each contoured frame consists of a grid of 92 points at 20 km spacing corresponding to the 120 km by 260 km box region shown in Figure 1. The frames are oriented 064°T, with north indicated by the arrow in Figure 10. The x and y axis refer to the distance in kilometers from the point 36.0°N, 73.5°W along and perpendicular to the orientation line.

The + marks indicate actual IES sites and the positions of these sites are listed in Table 1.

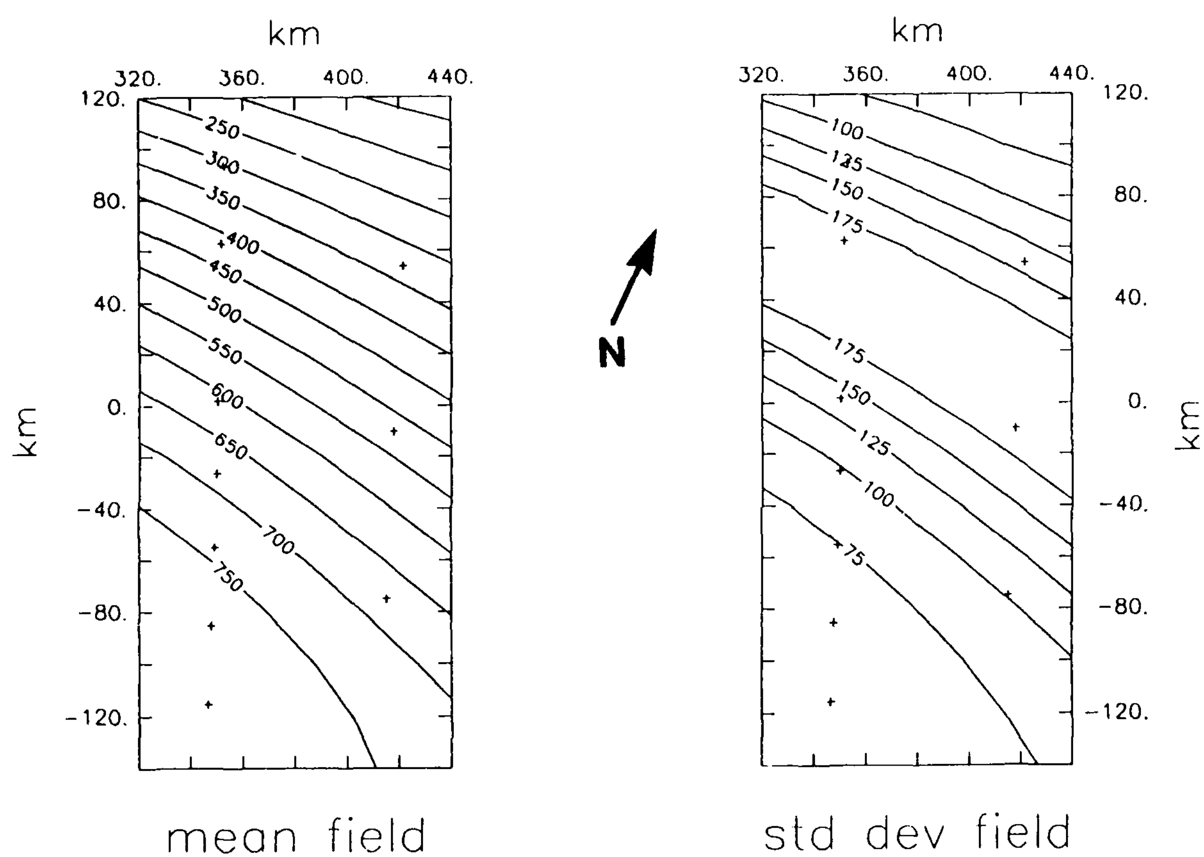


Figure 10. Mean field (left) for the May 1985 to June 1986 data, and standard deviation (rms) field (right) are contoured in plan view. North is indicated by the arrow.

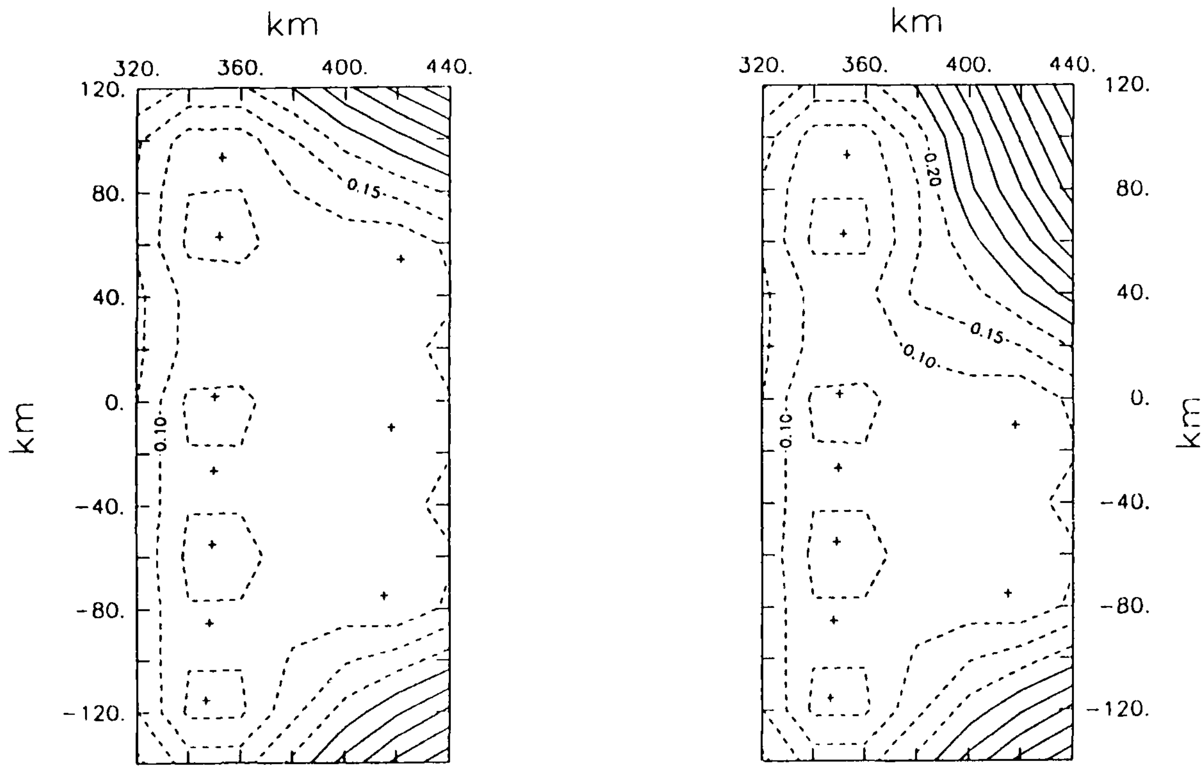
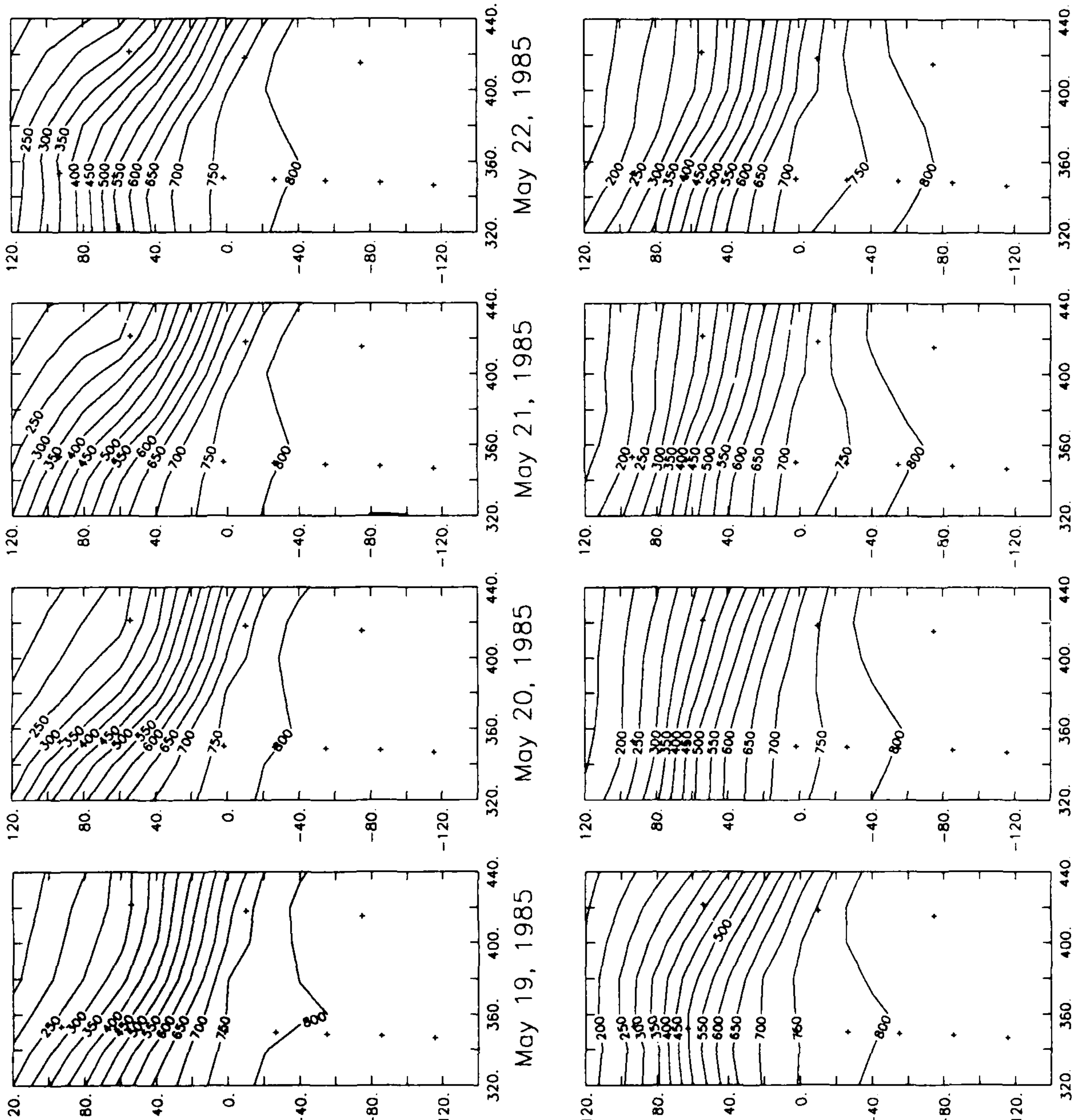


Figure 11. Error (percent standard deviation) fields are contoured at 5% intervals, with the dashed region corresponding to $\leq$ 20% error. The right error field applies to the Z_{12} fields in Figure 12 for November 24, 1985 through January 28, 1986, when the IES at site H1 failed. The left error field applies for May 18, 1985 through November 23, 1985, and January 29, 1986 through June 19, 1986. The horizontal scales are the same as those labelled in Figure 10.

Figure 12. The 12°C isotherm depth (Z_{12}) field are shown at daily intervals from 19 May, 1985 to 20 June, 1986. The maps are shown for 1200 GMT on the date indicated at the bottom of each map. The Z_{12} field is contoured at 50 m intervals. Refer to Figure 11 for the percent standard deviation error associated with these maps.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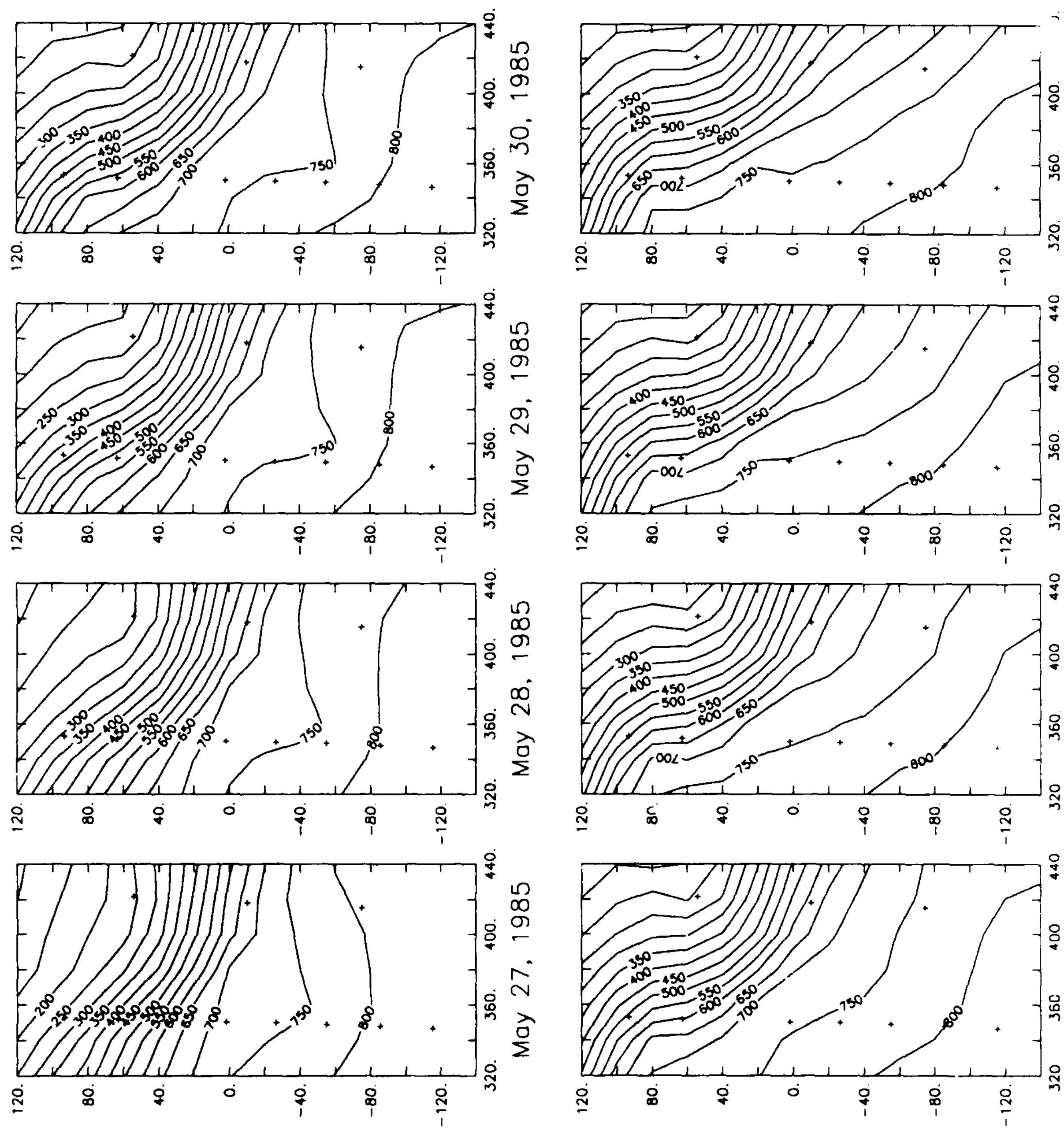

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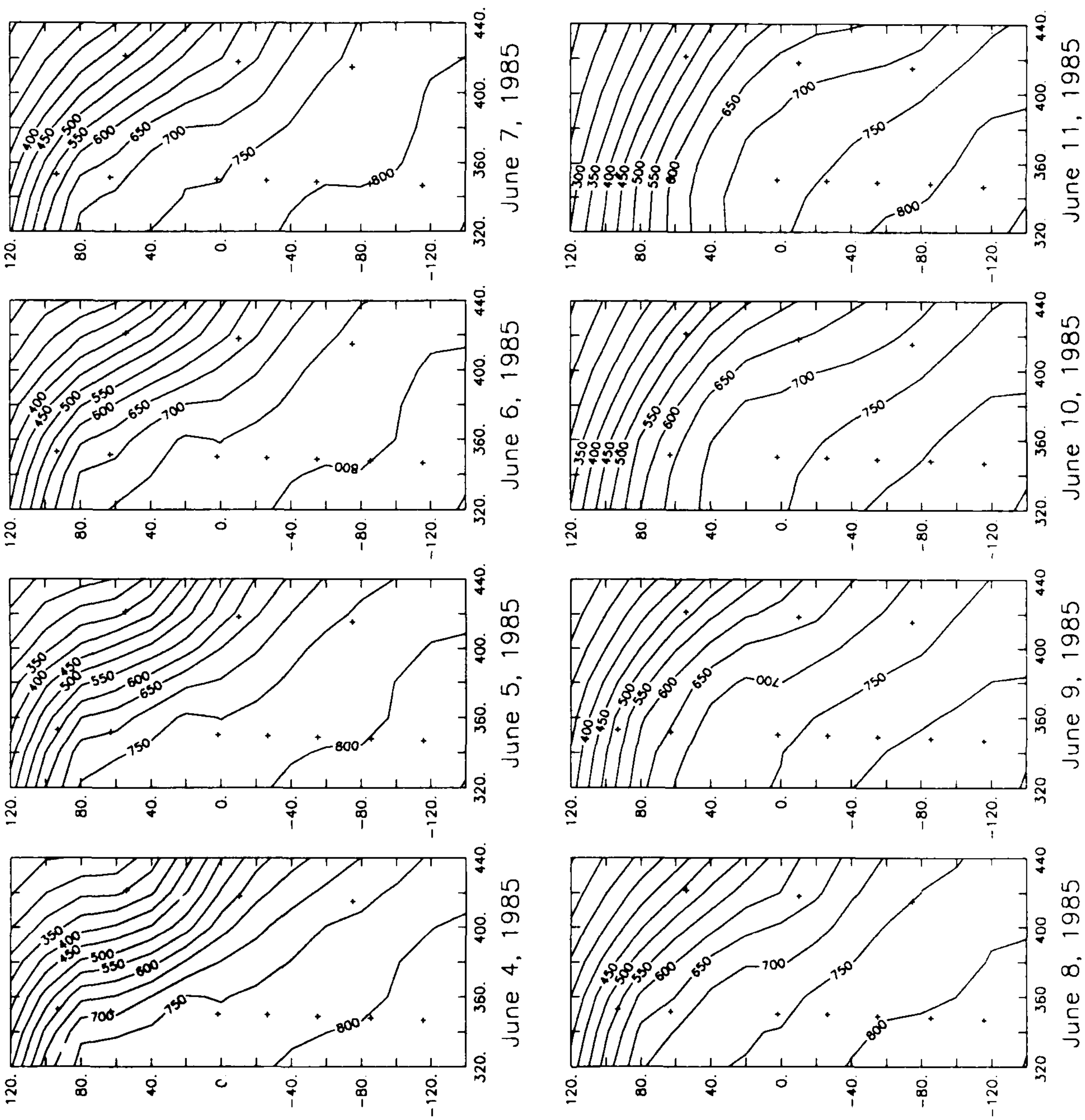
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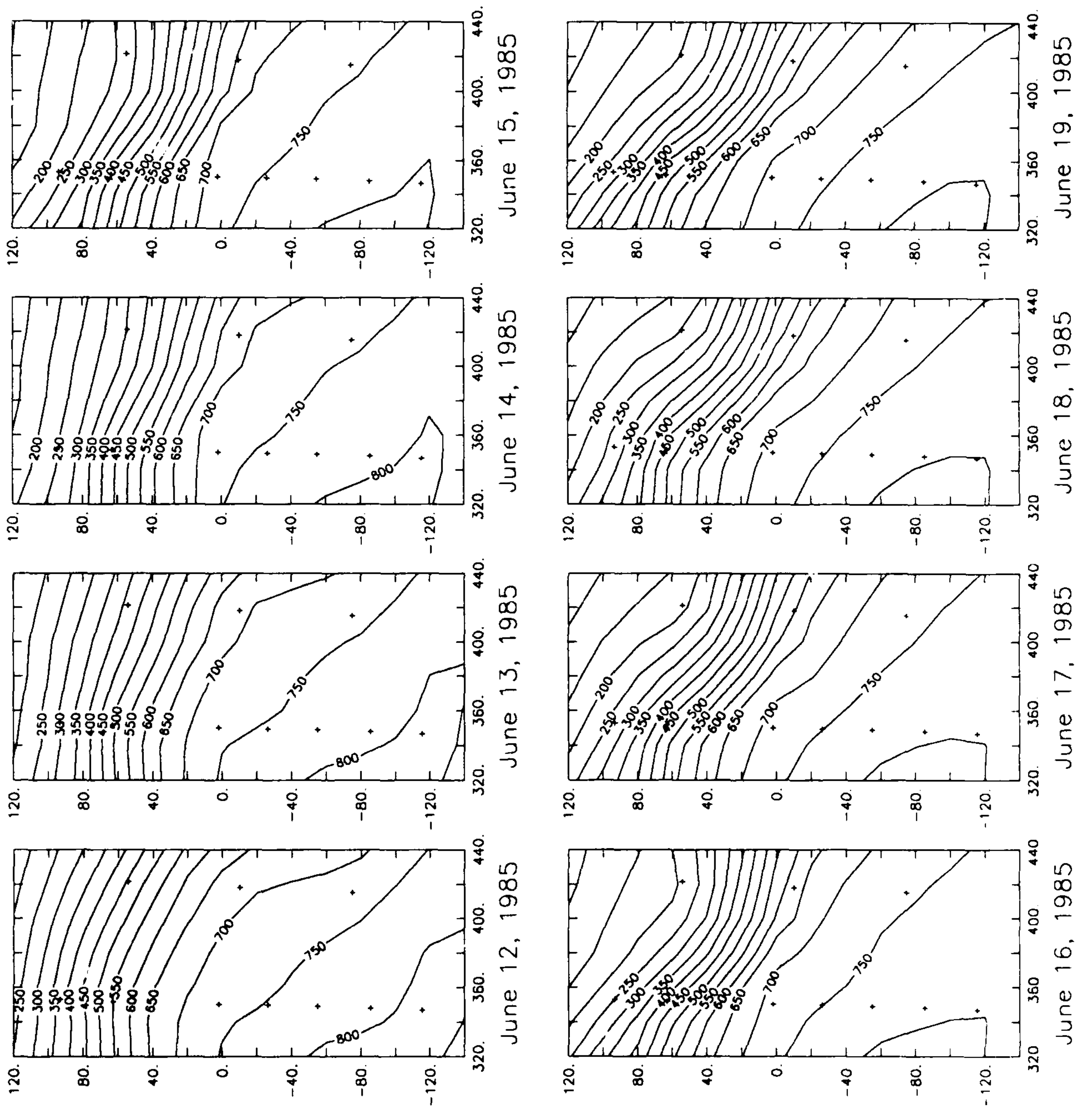
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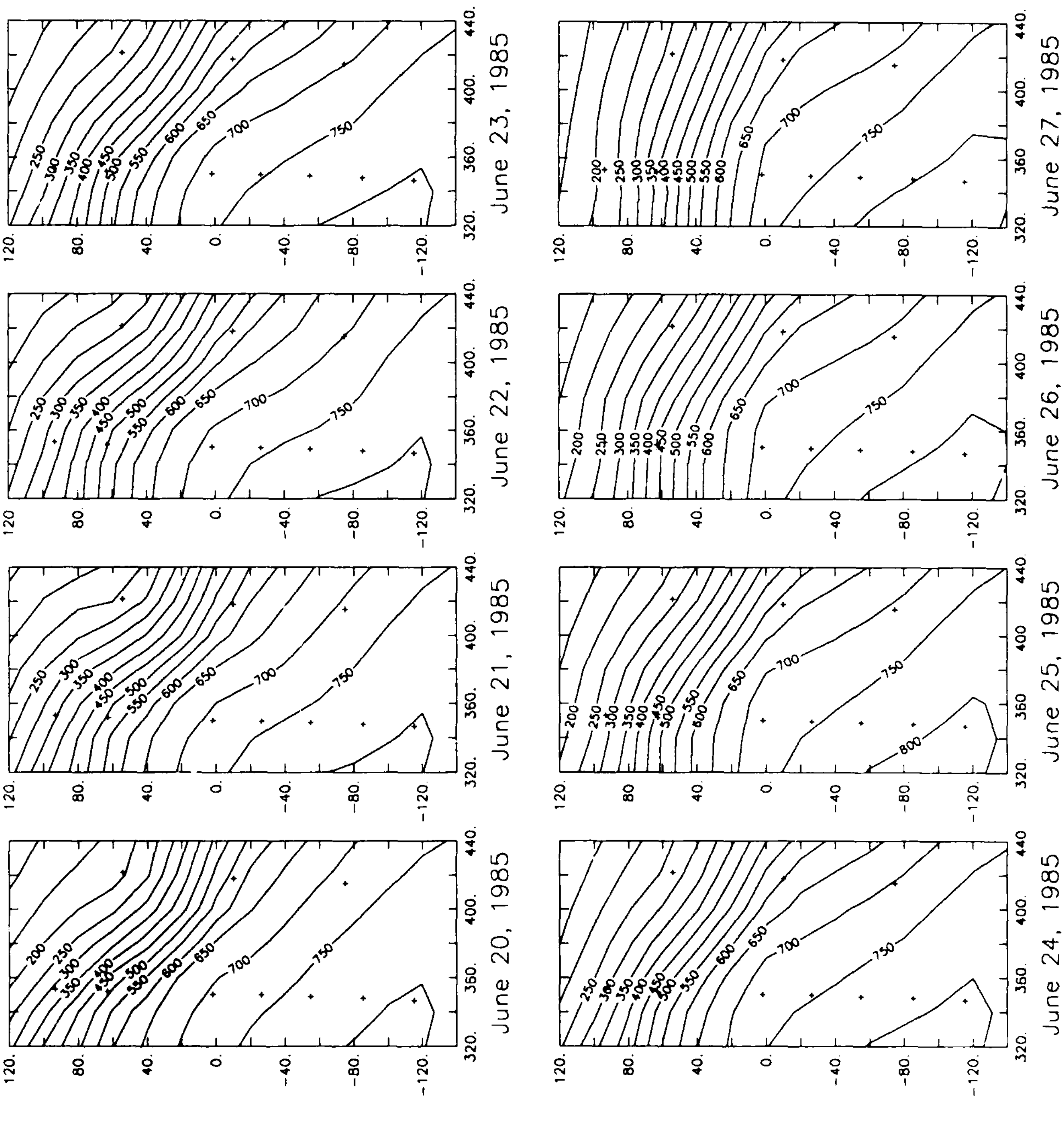
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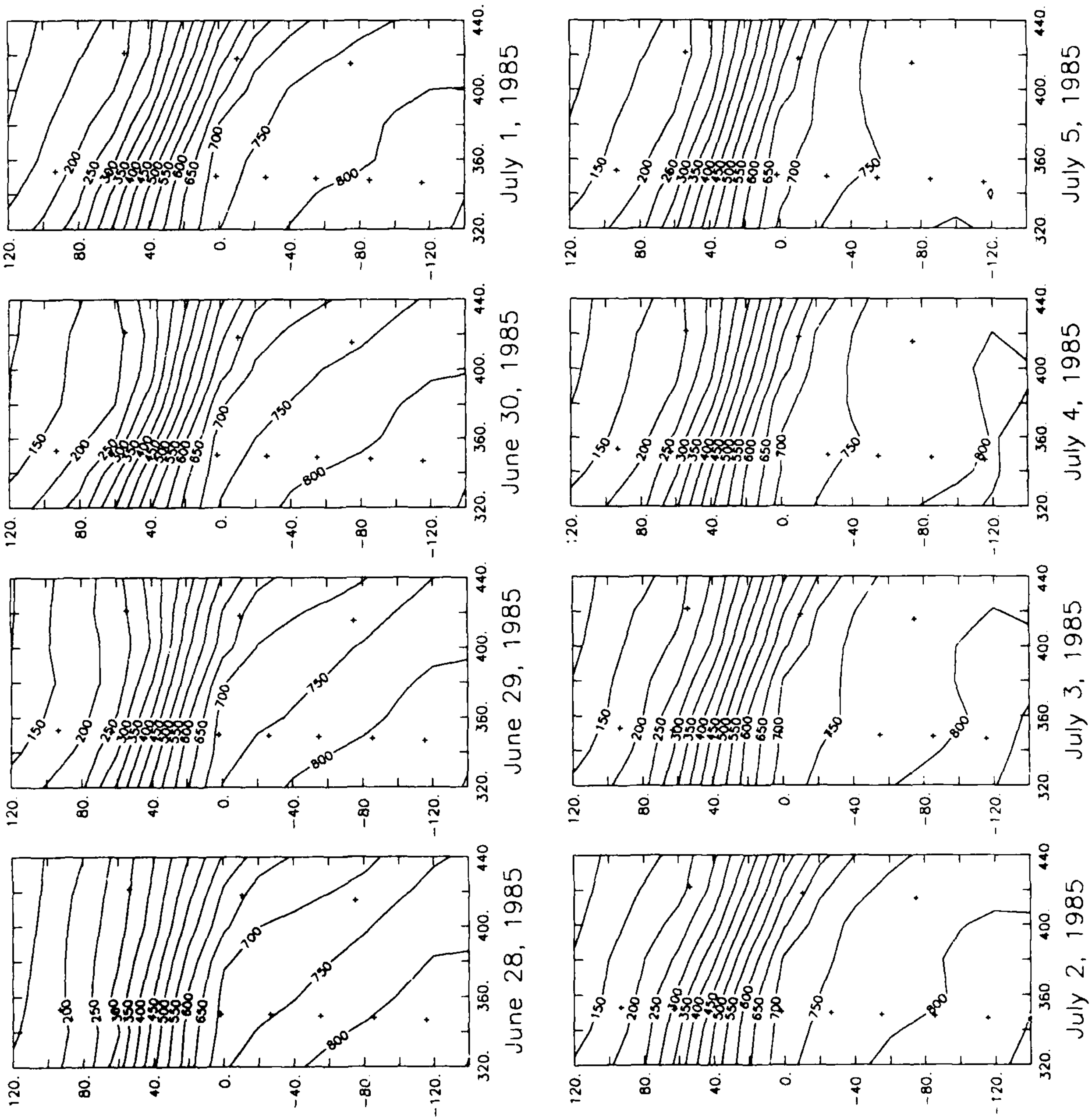
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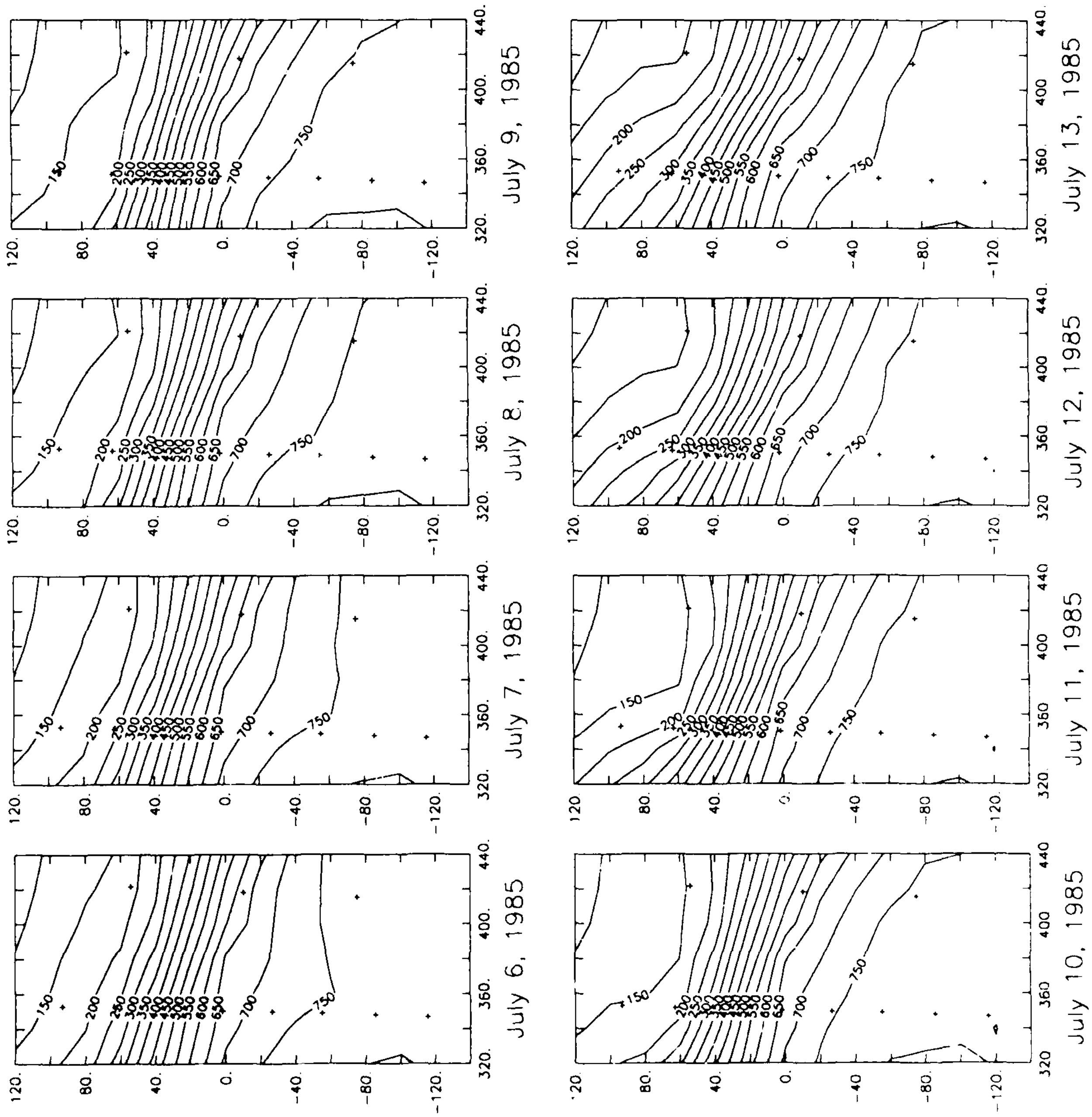
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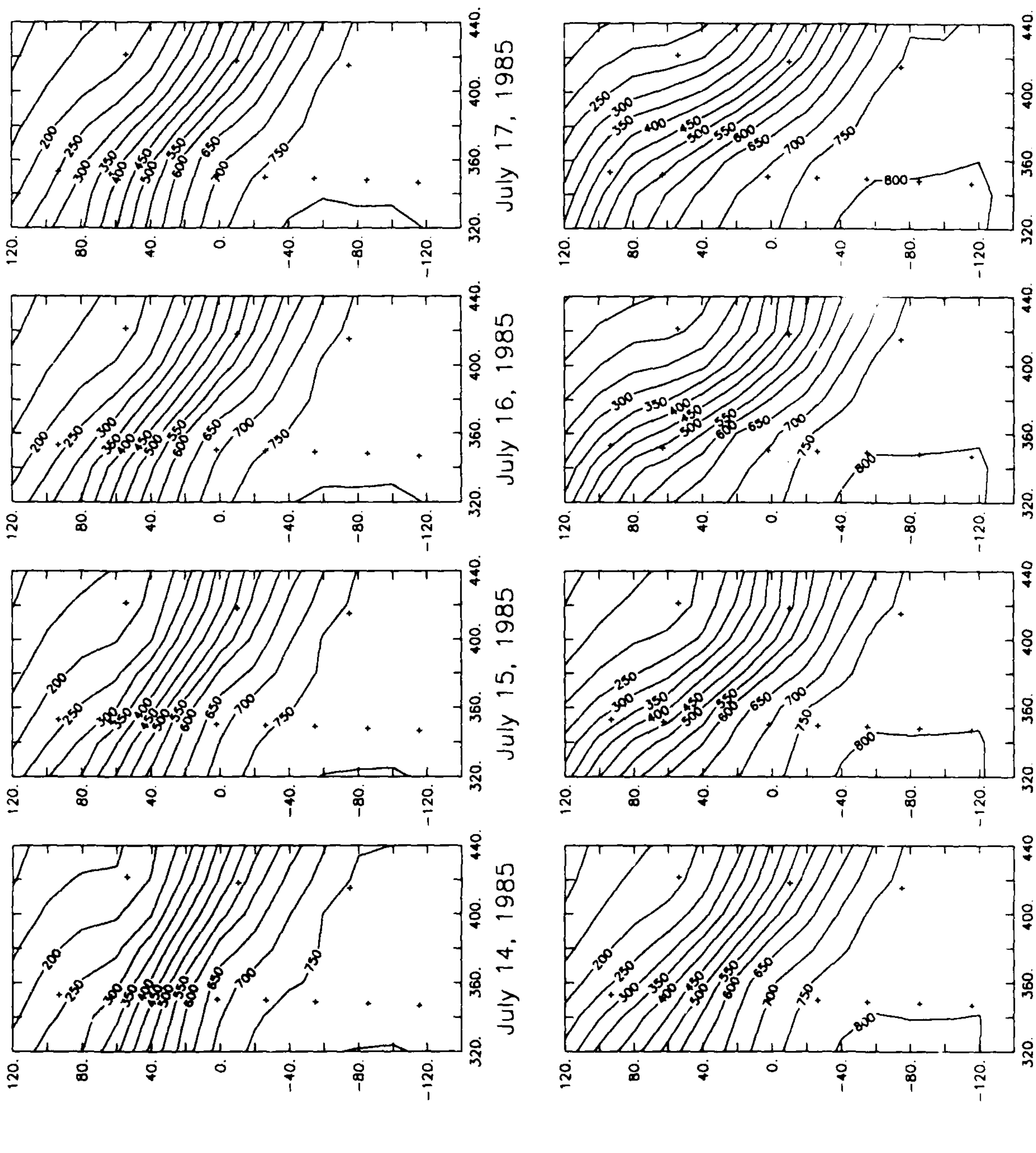
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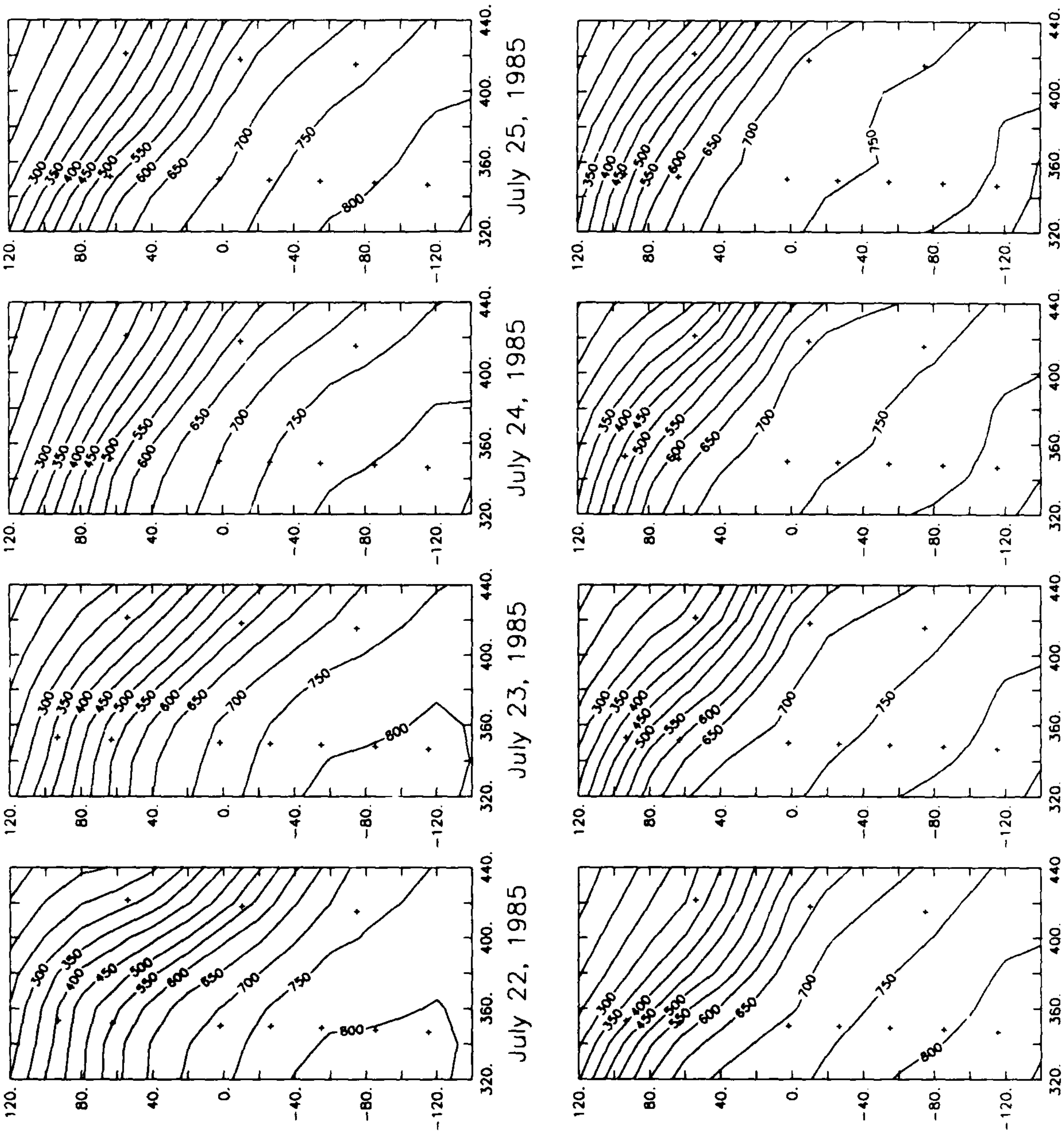
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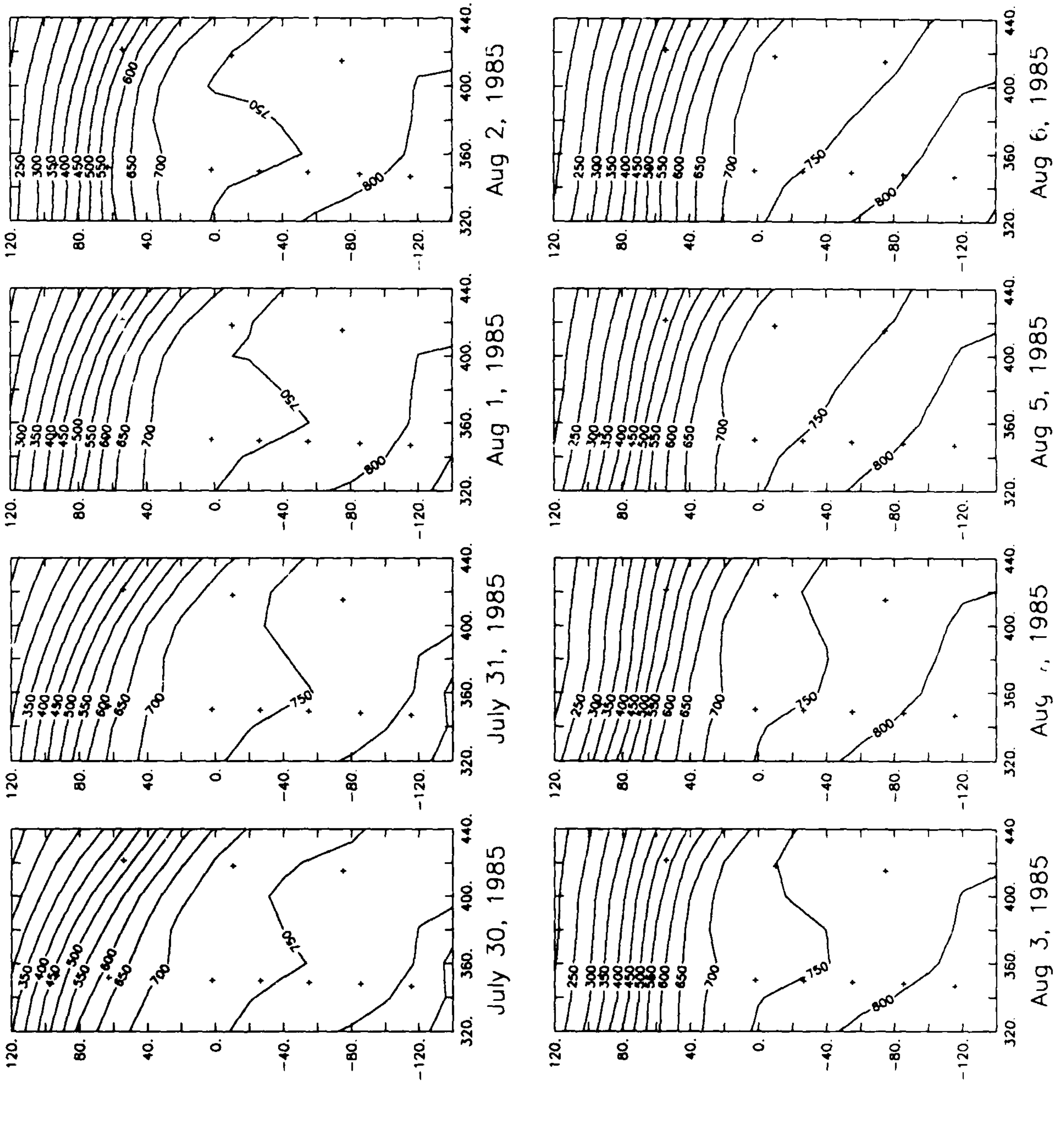
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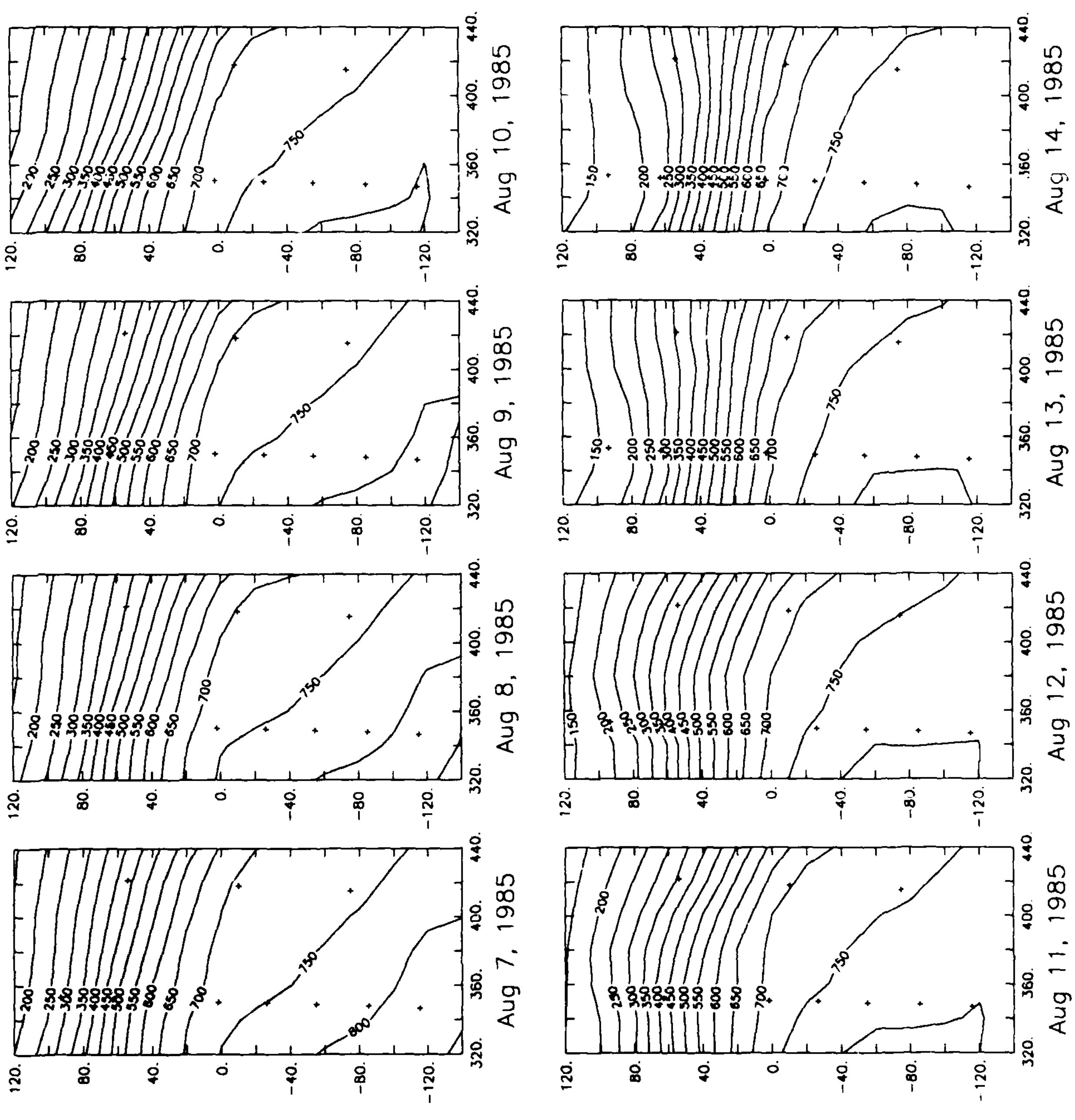
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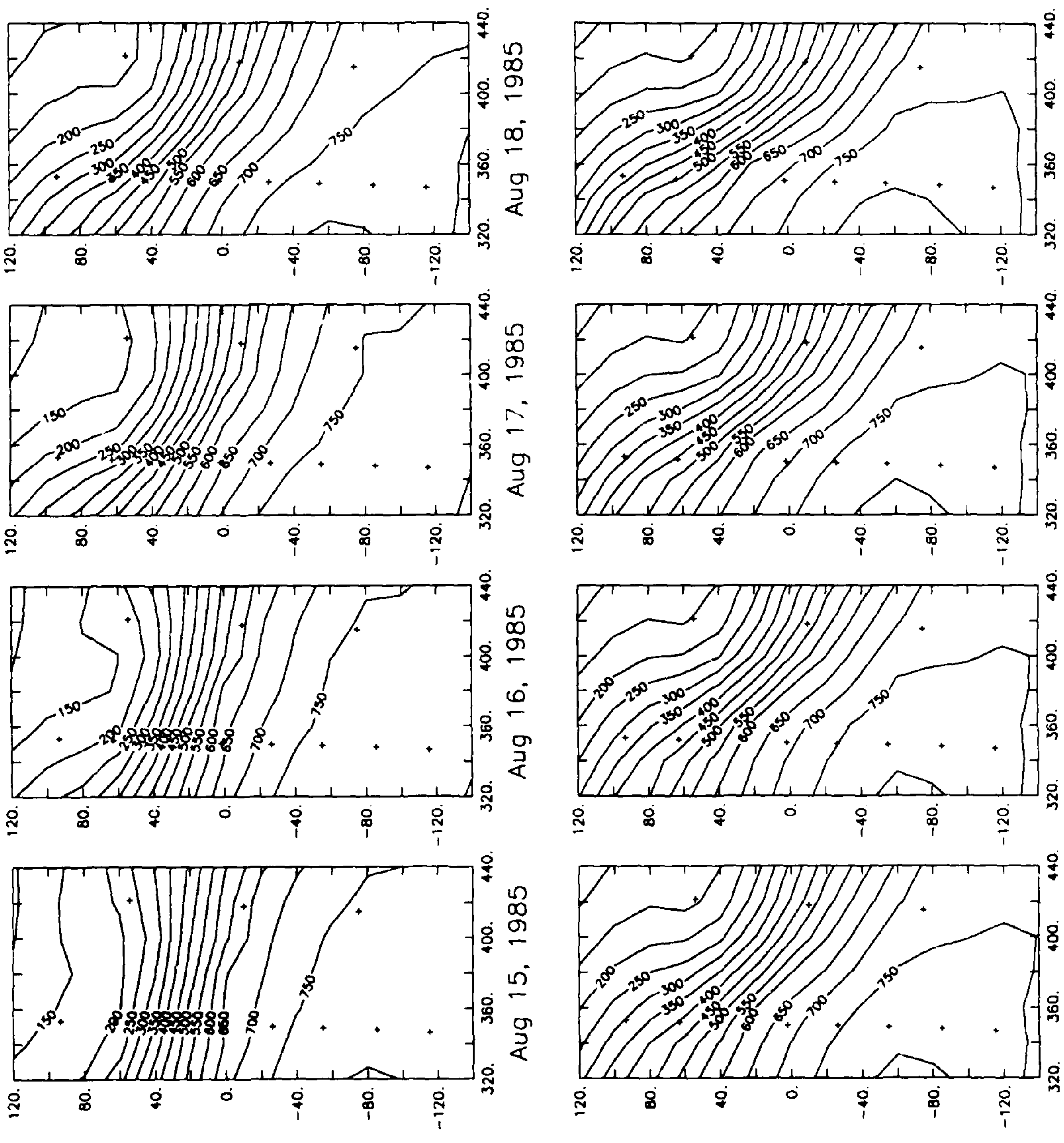
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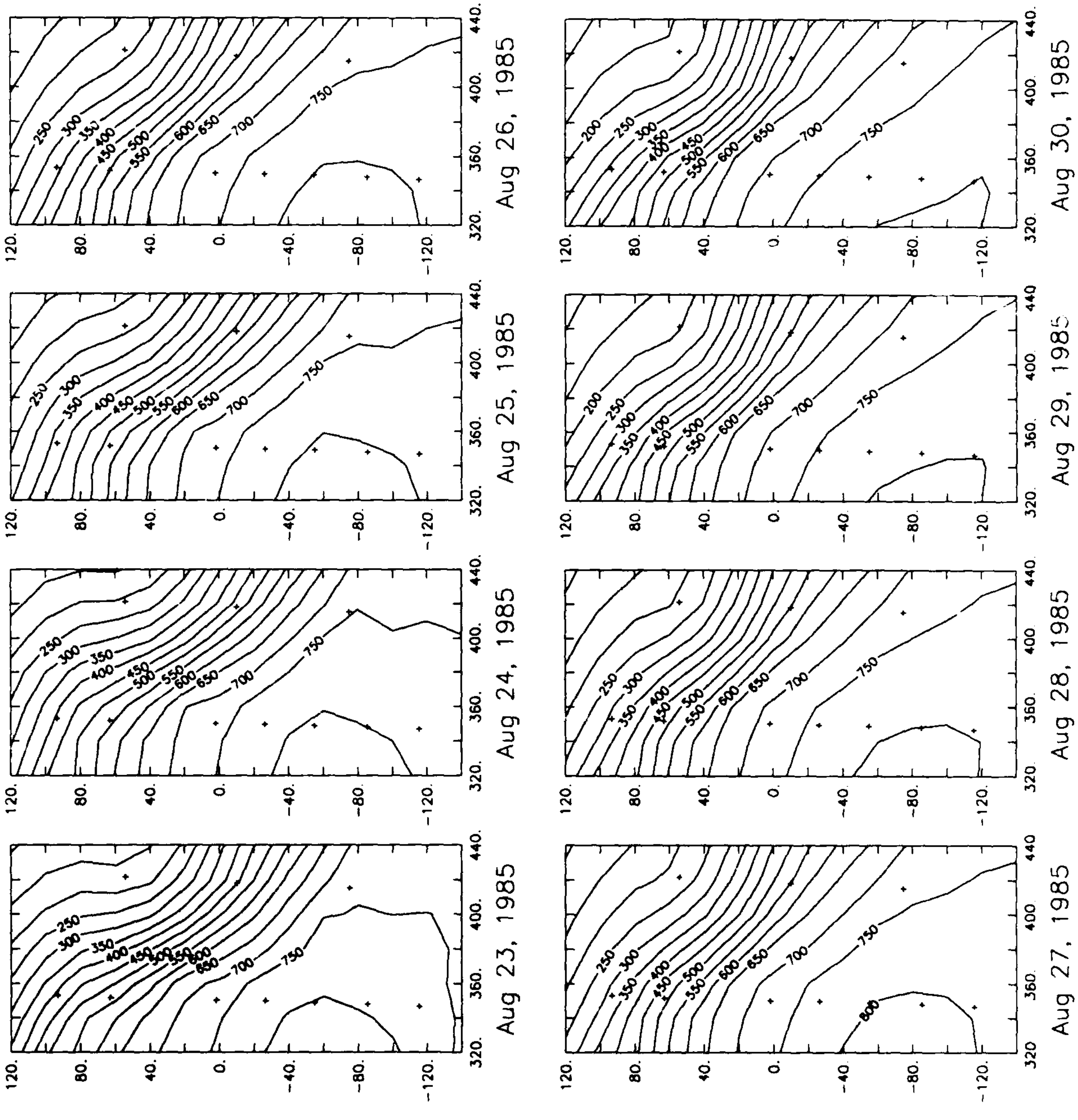

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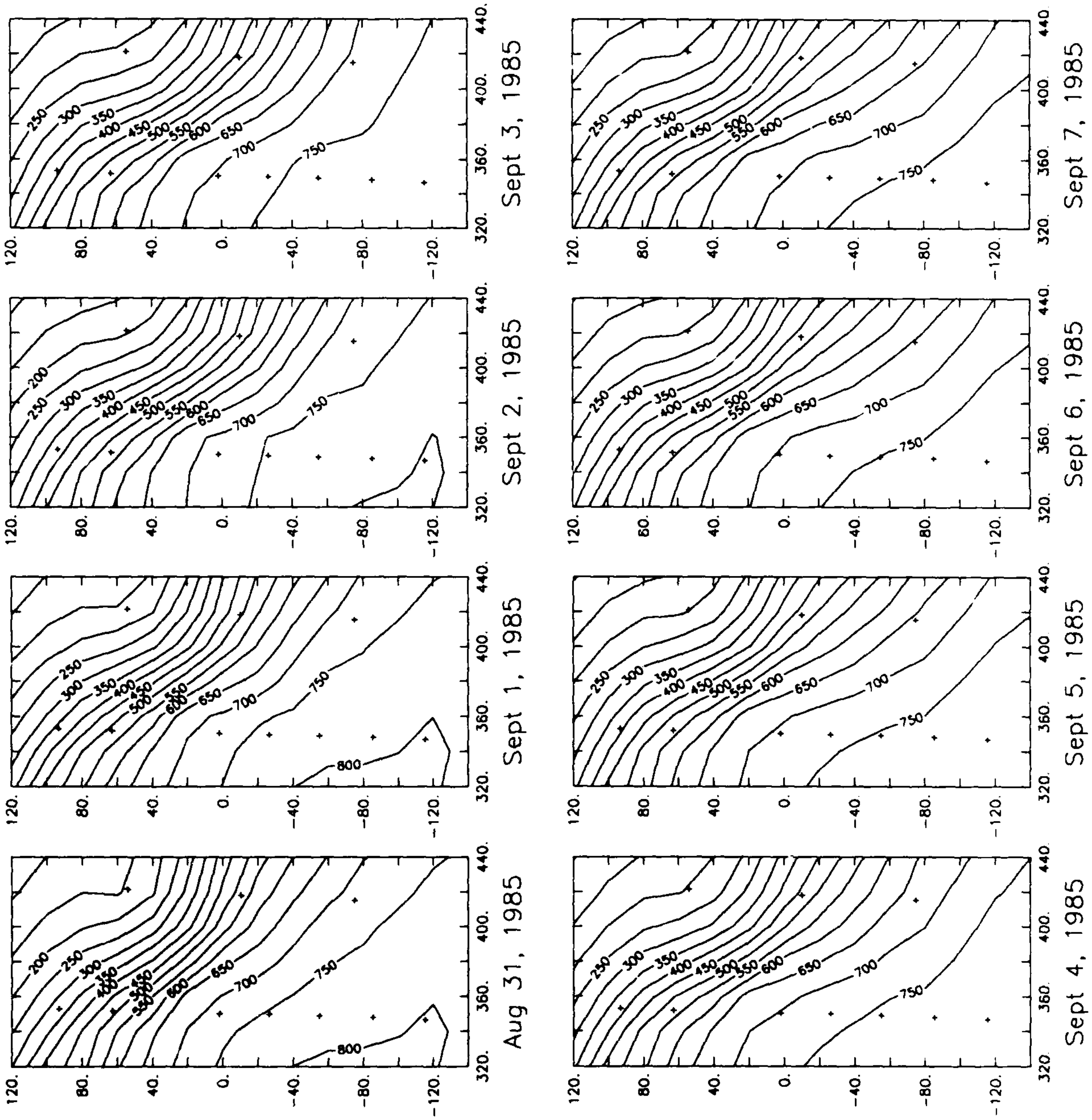
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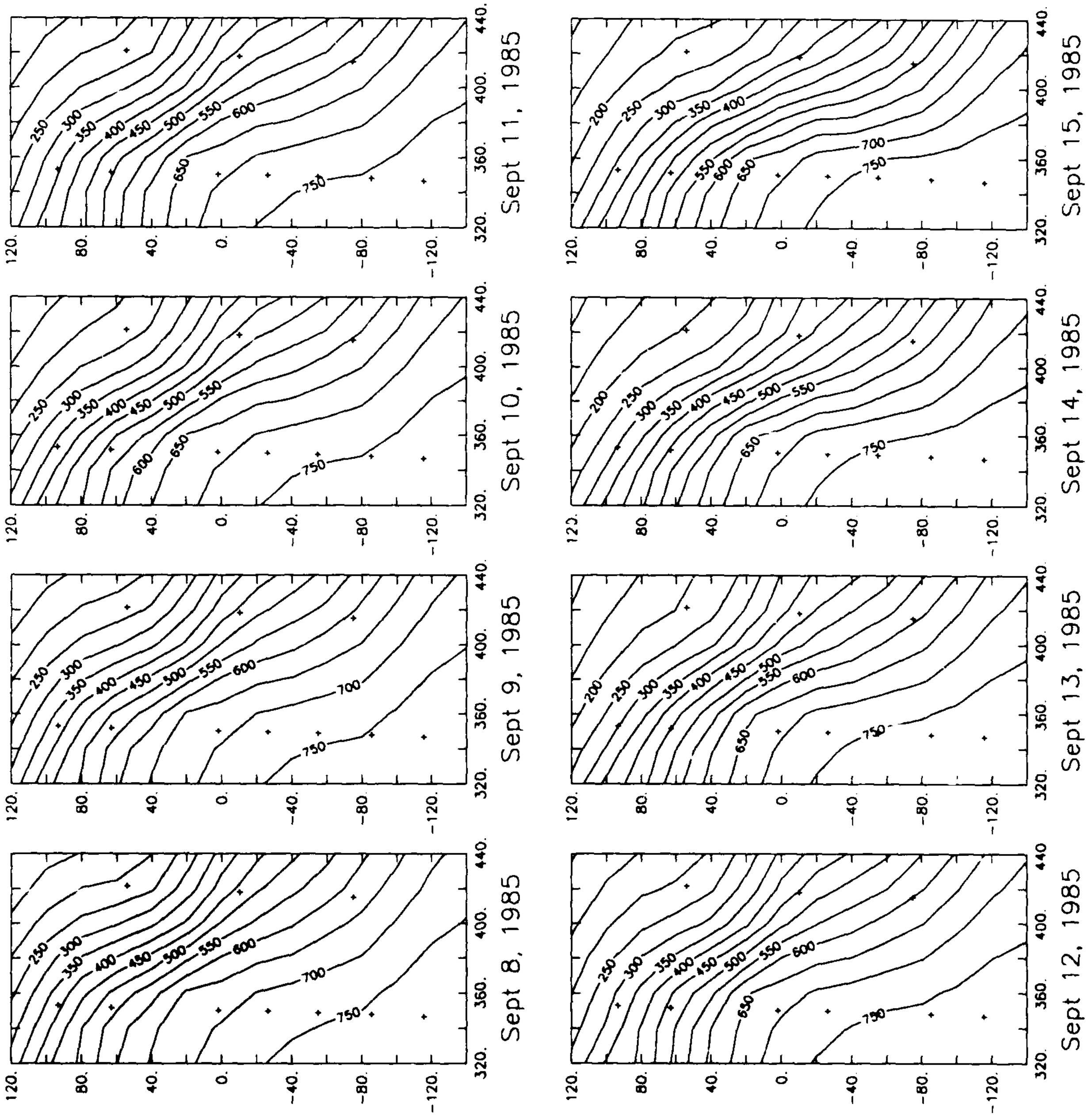
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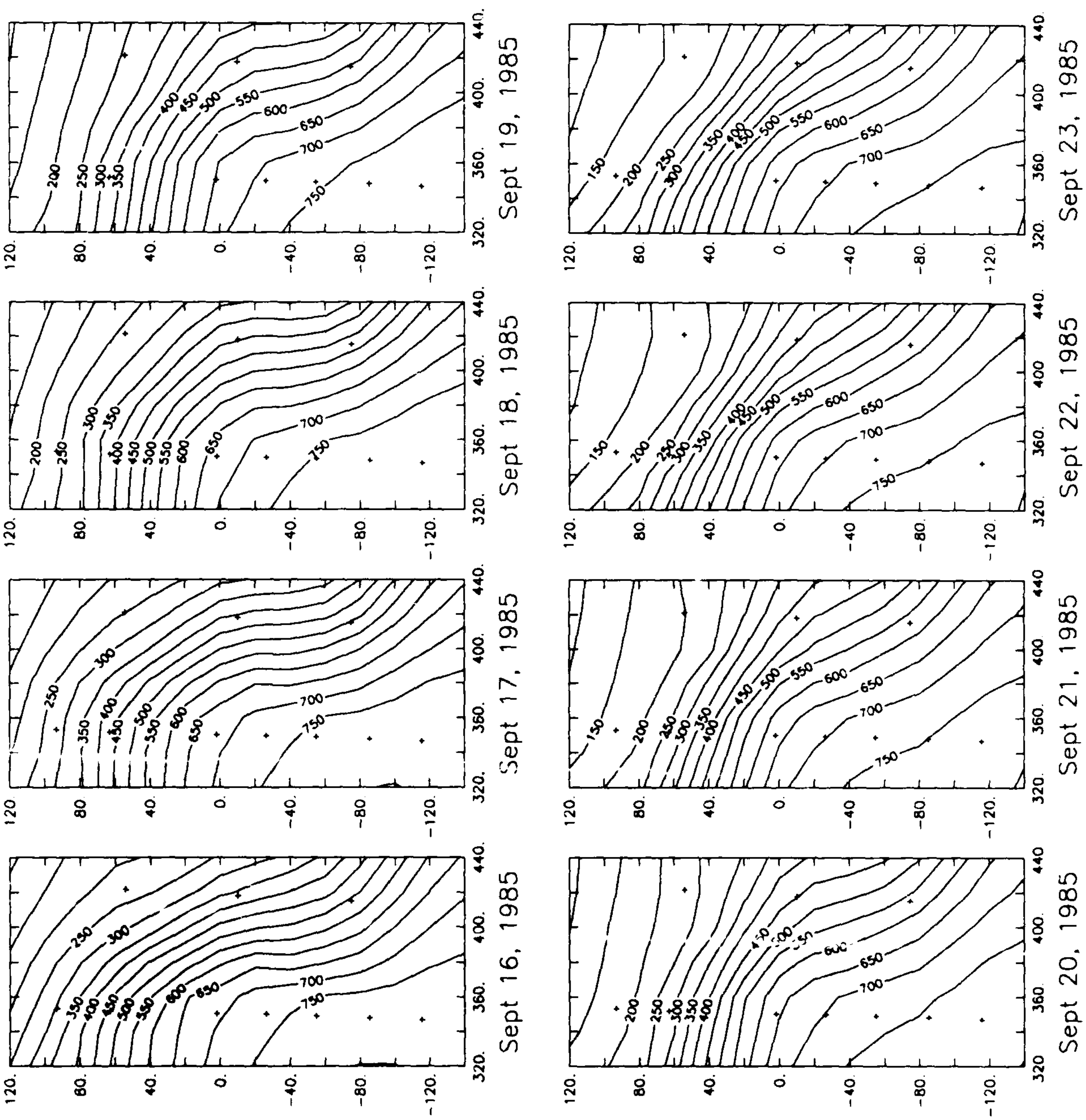
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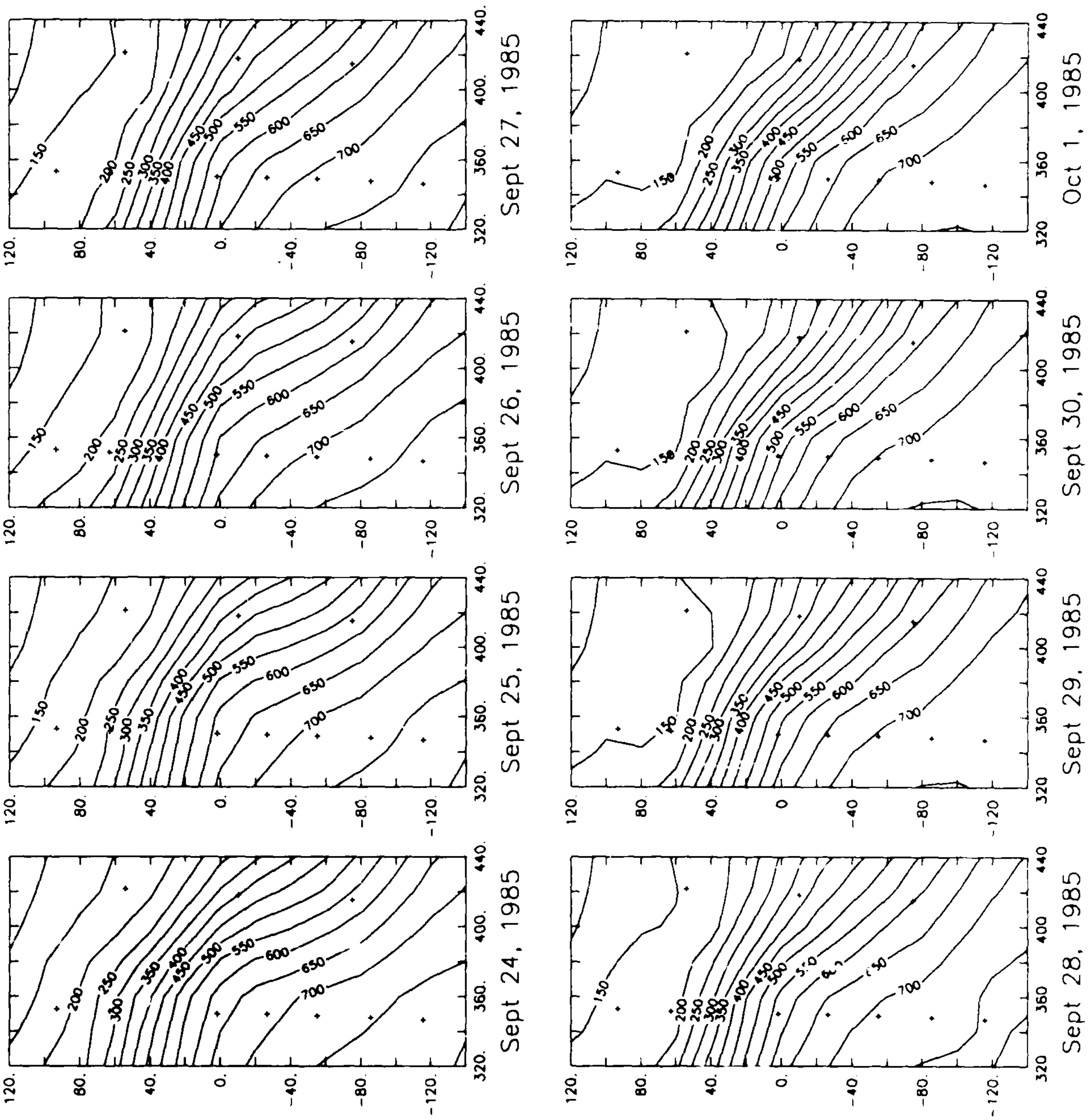
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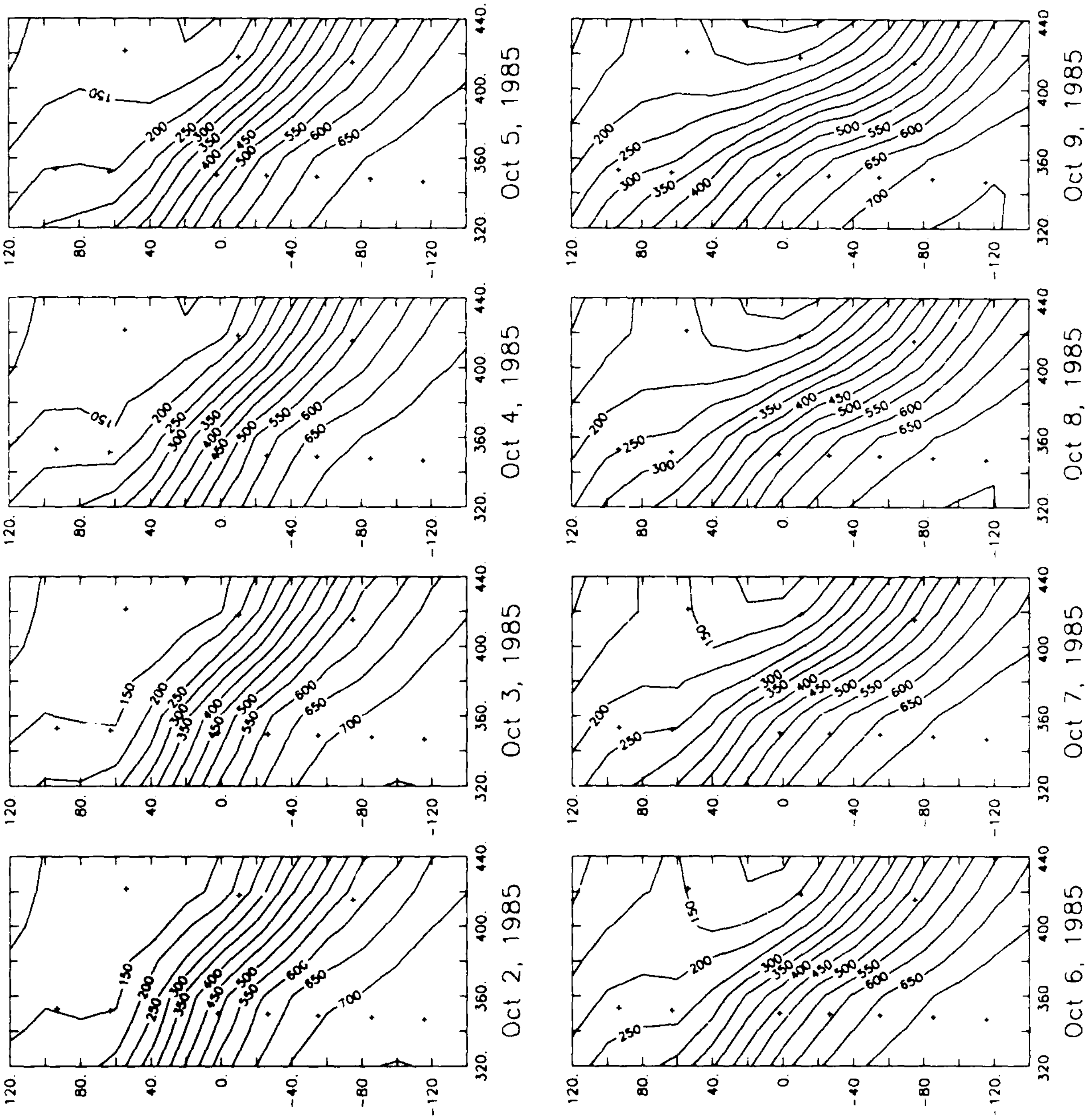

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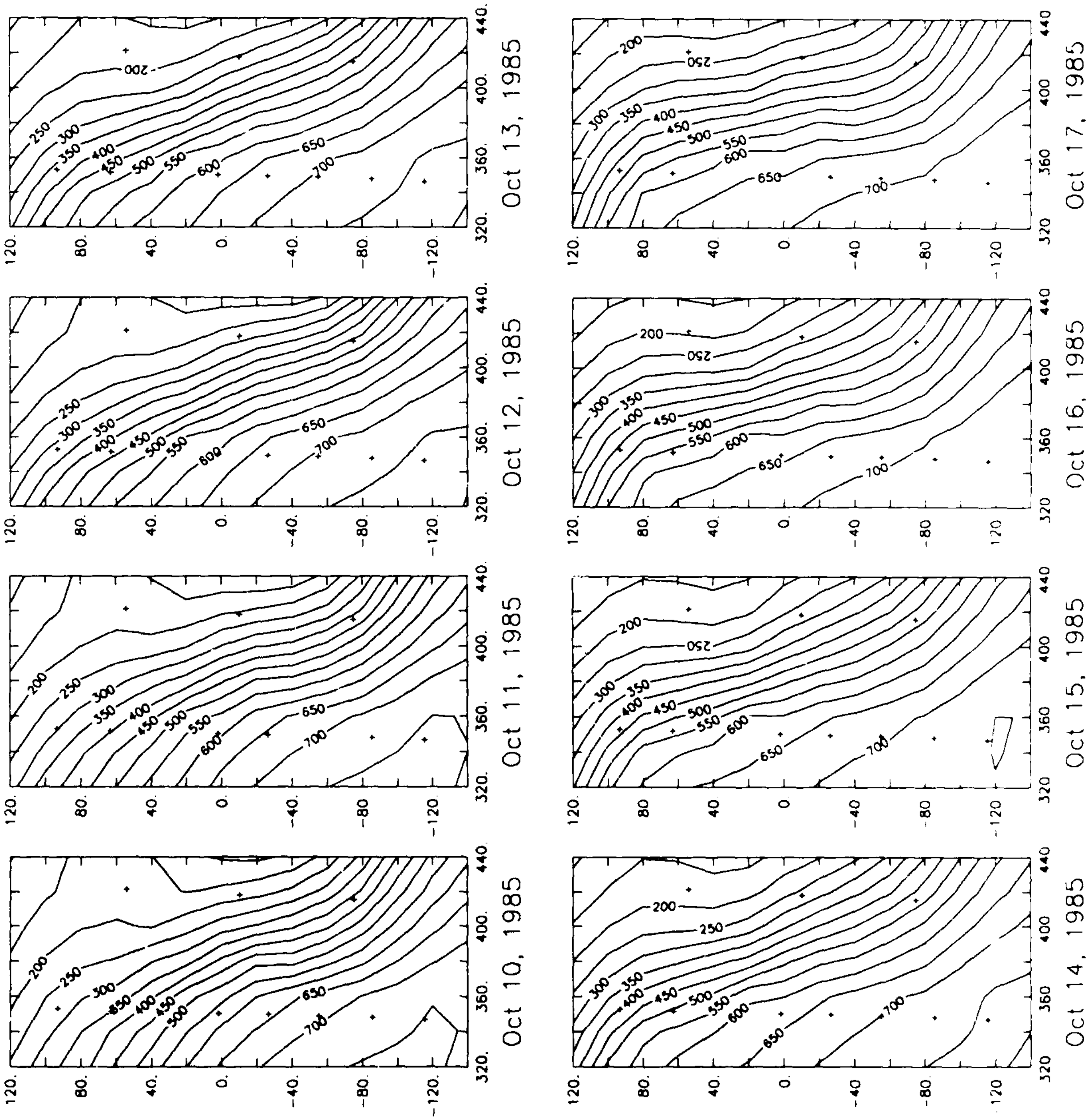
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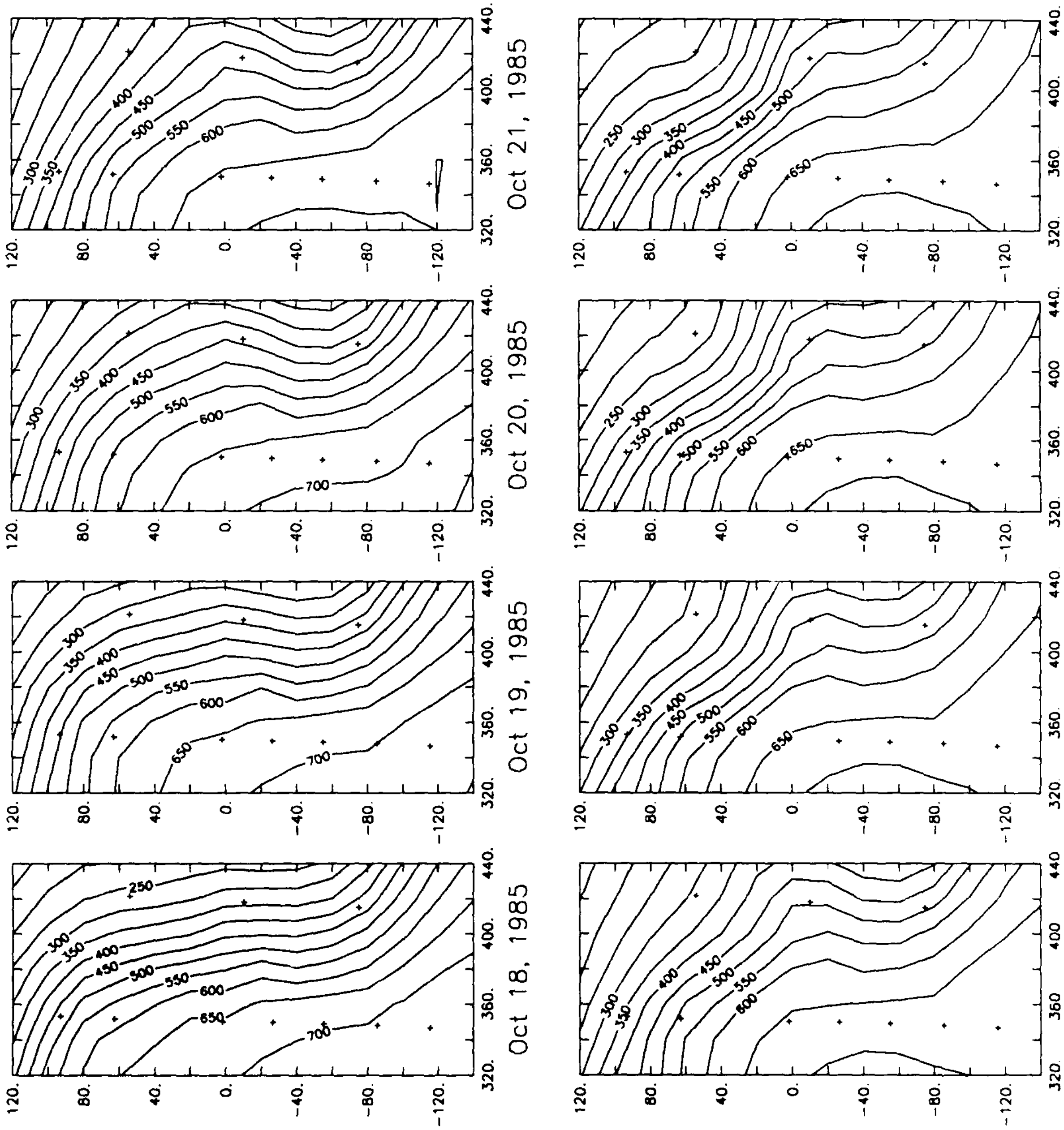
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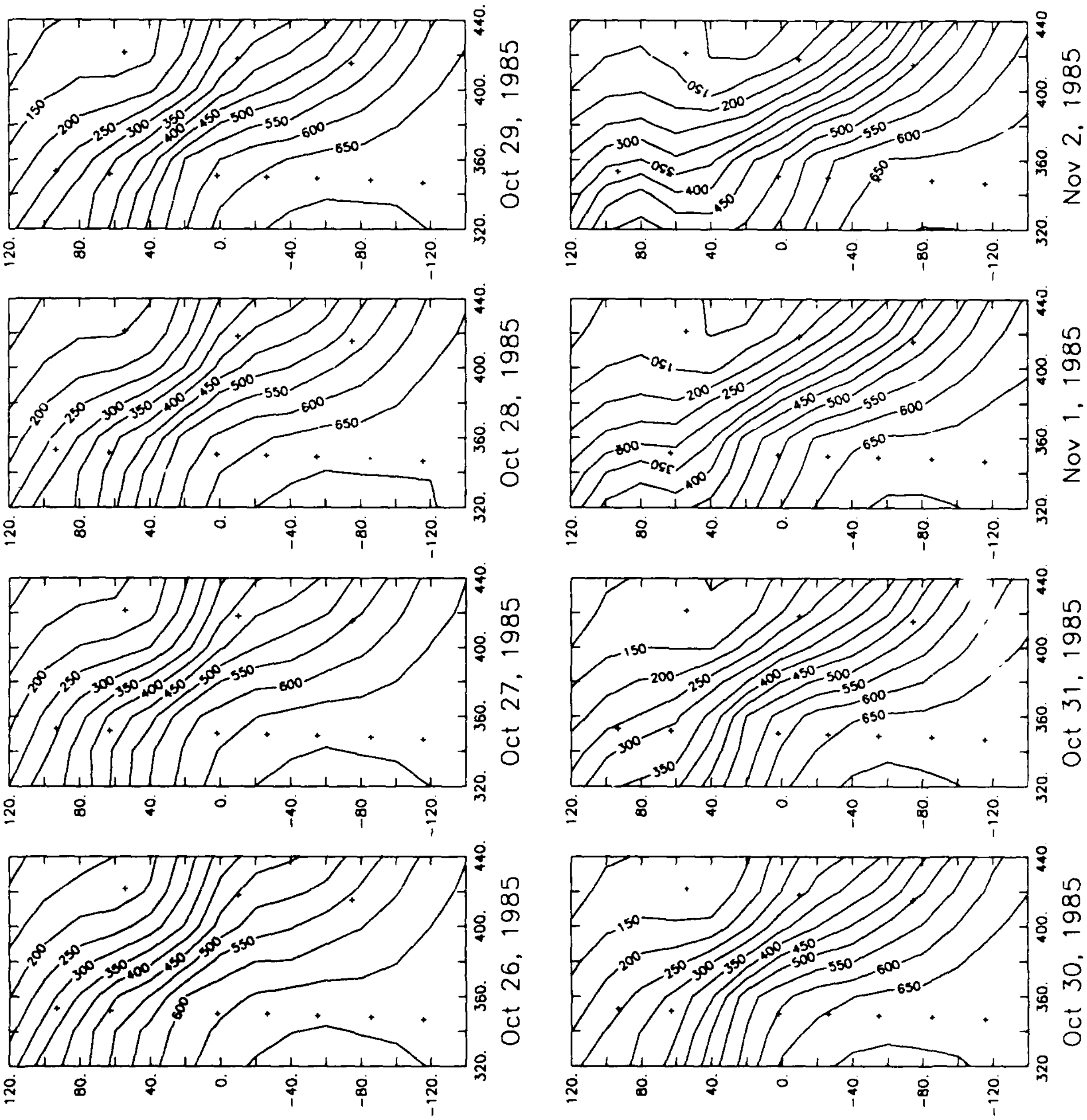
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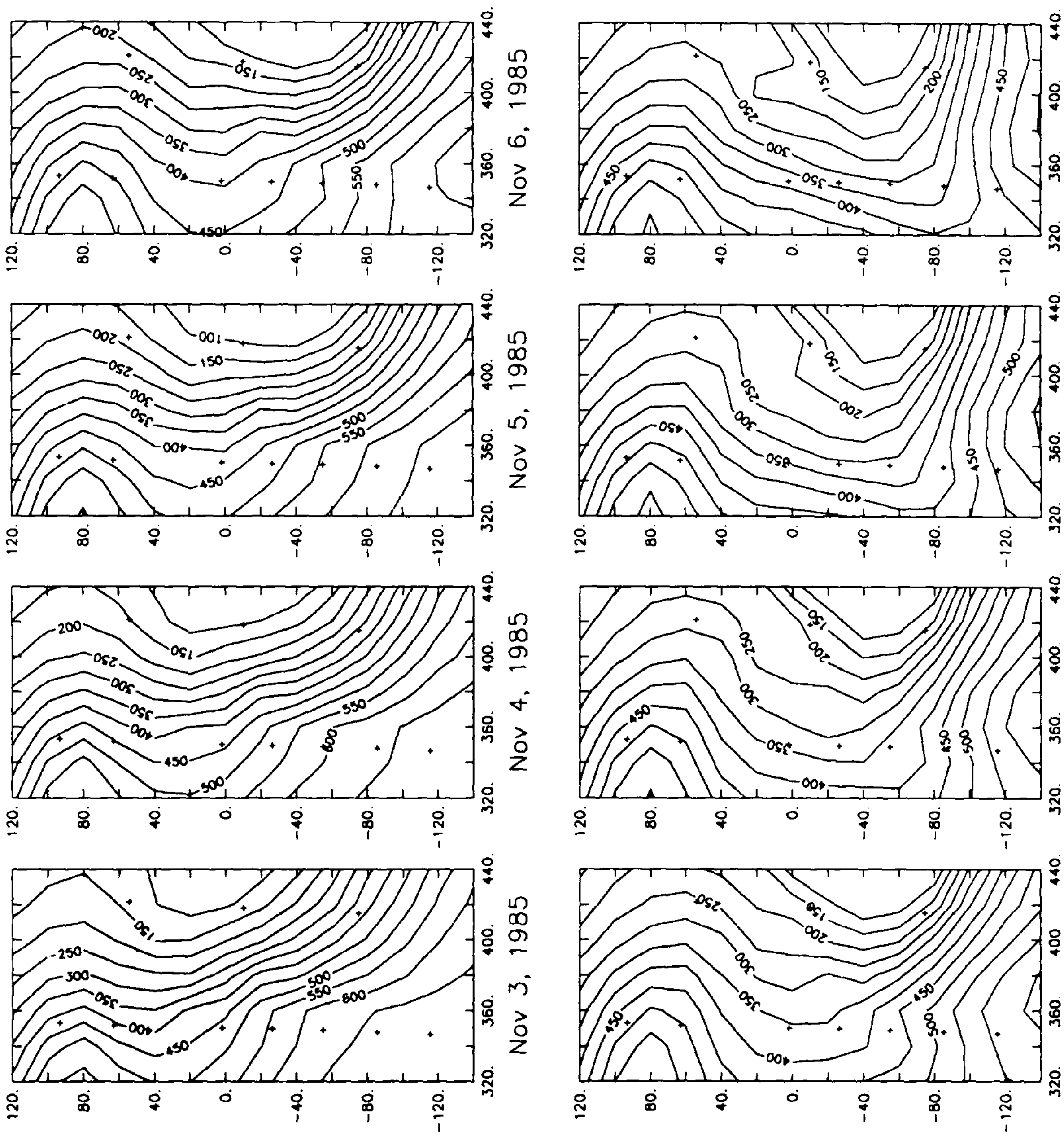
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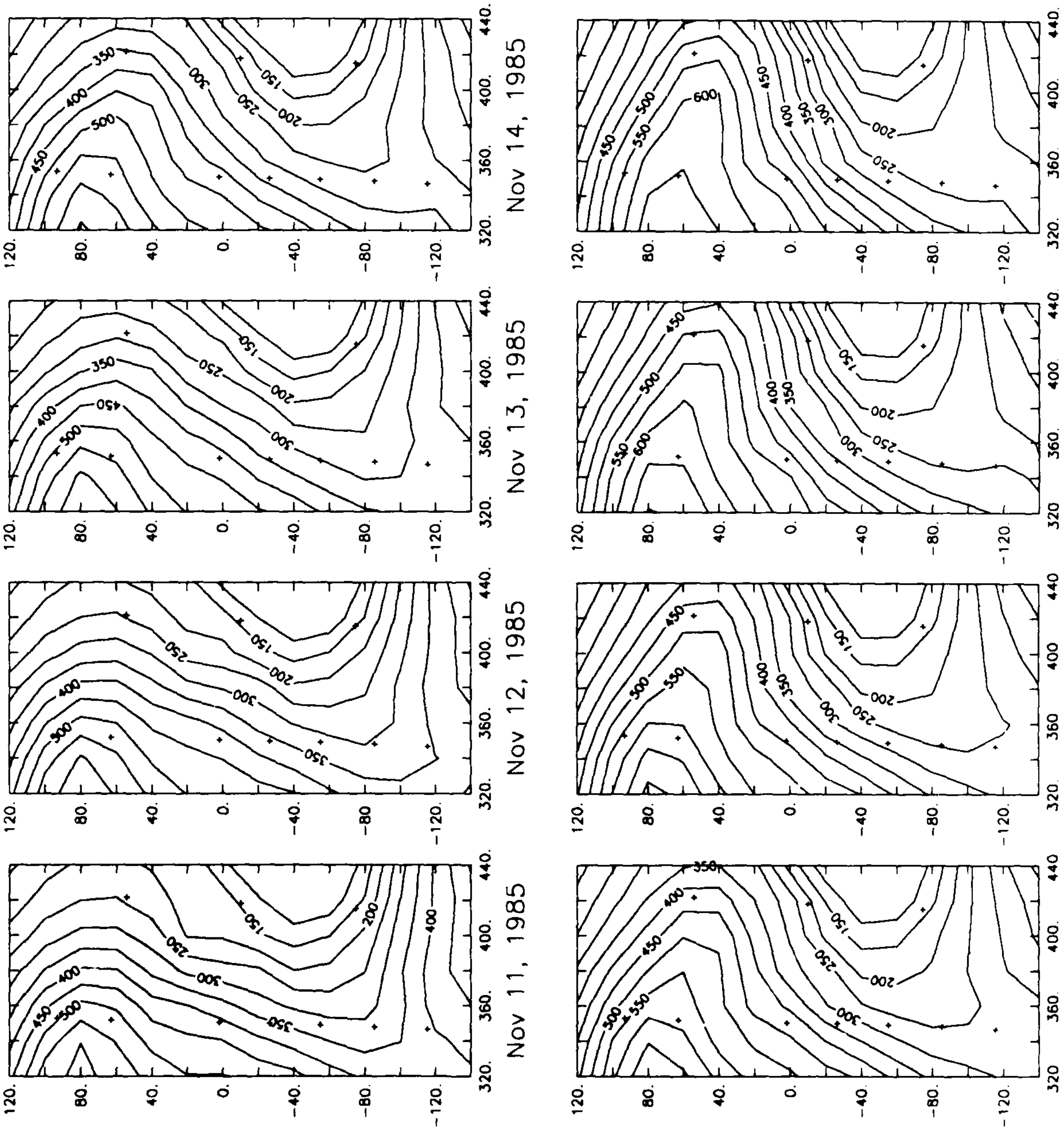

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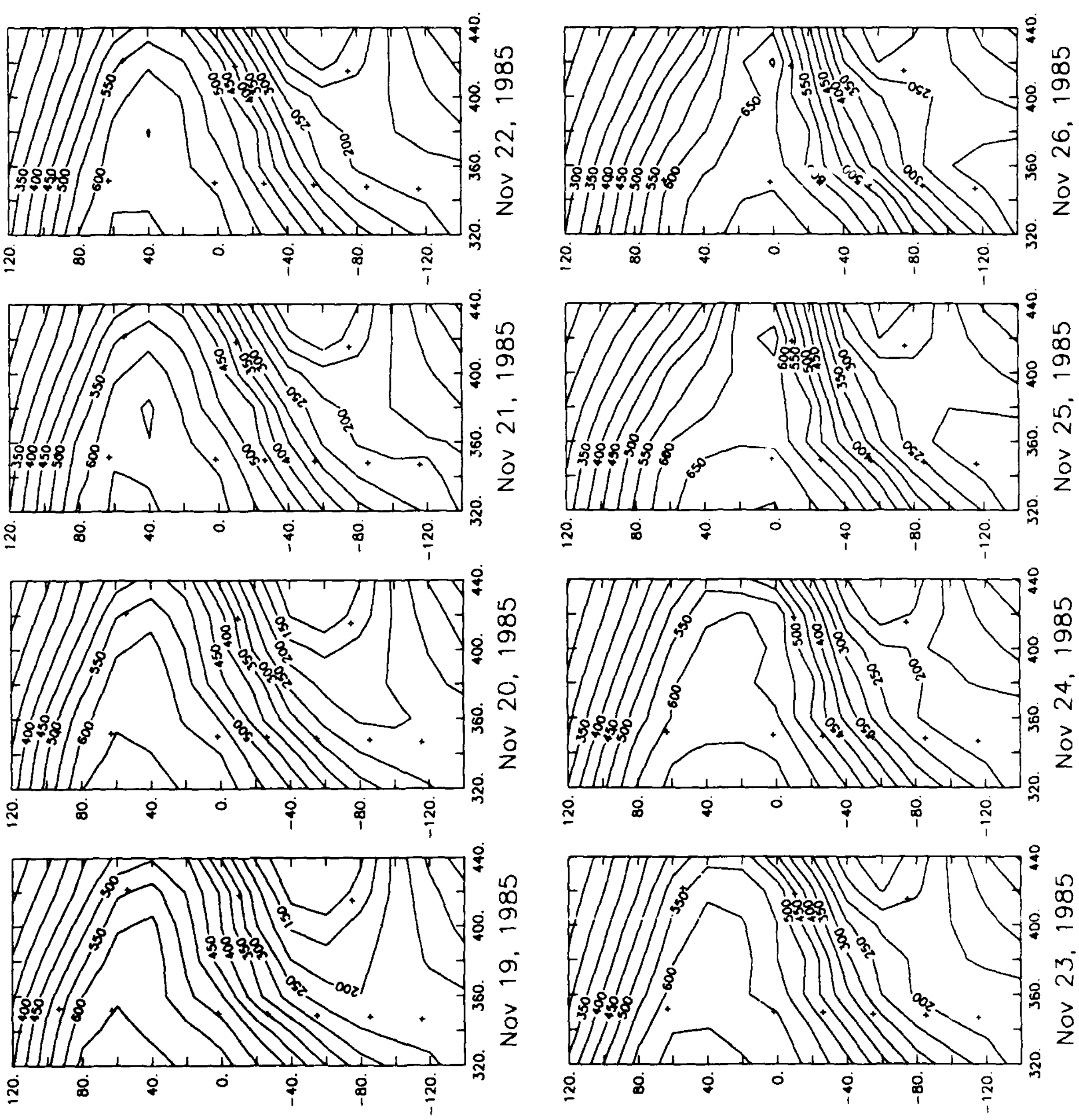
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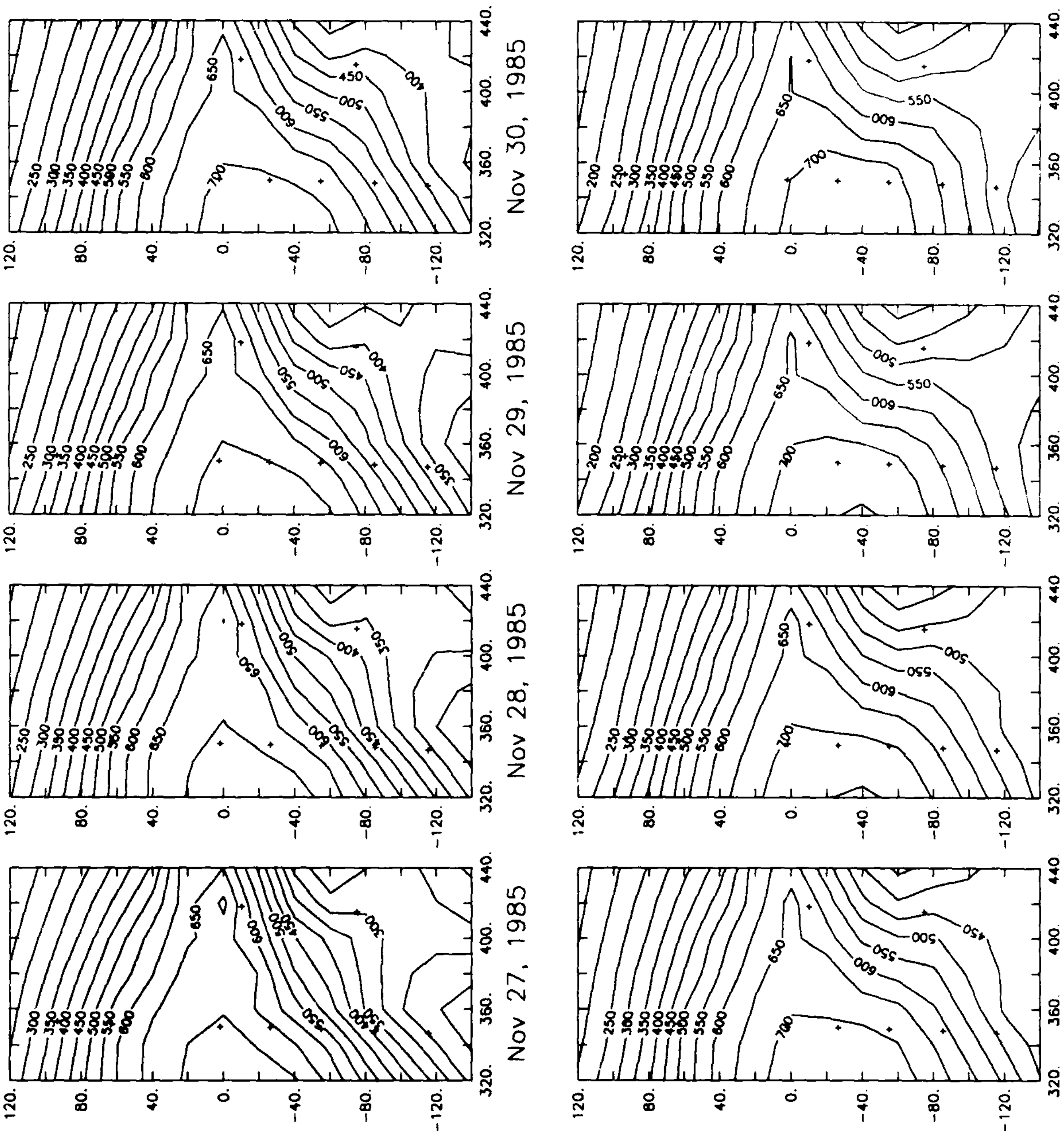
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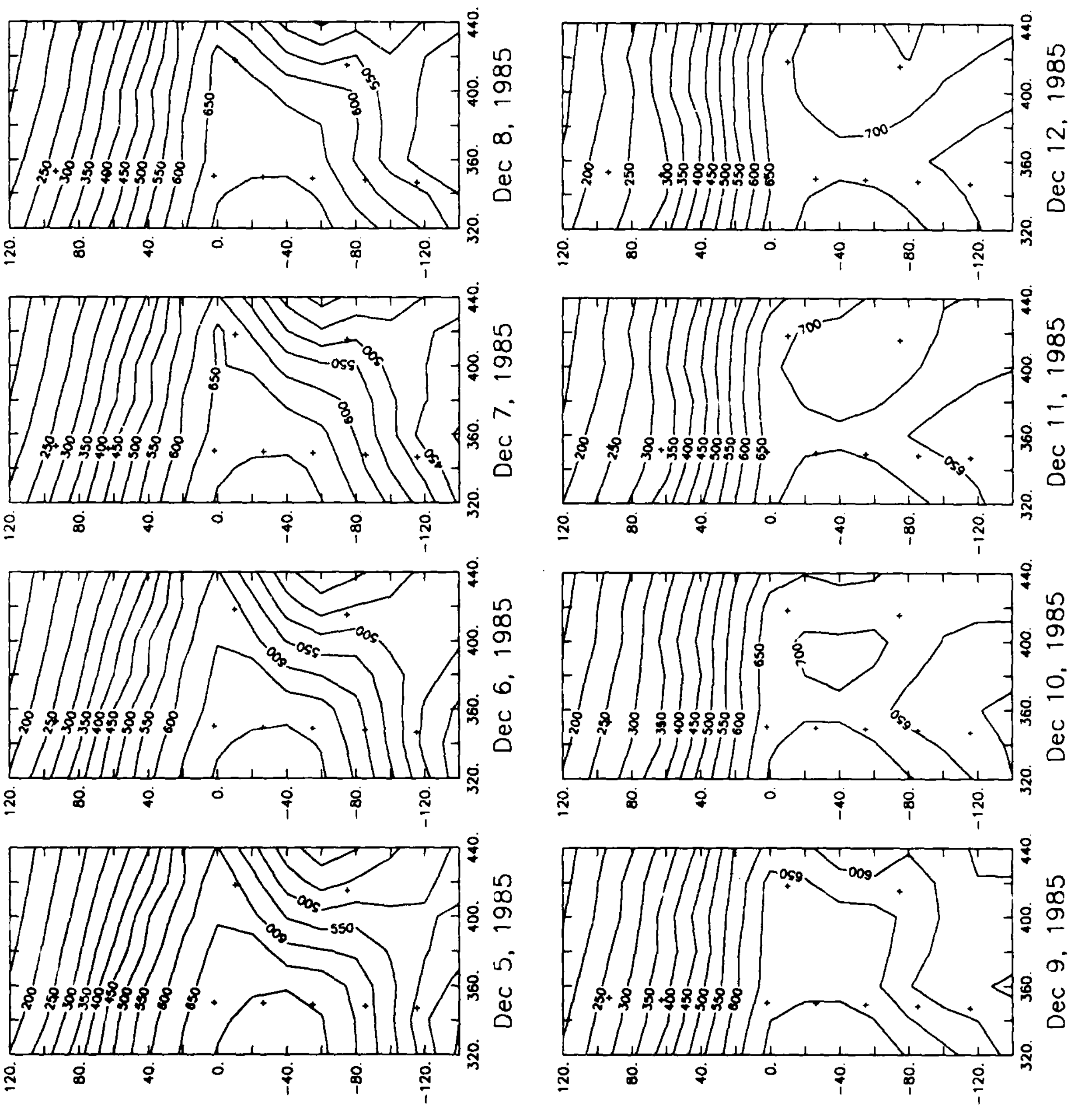
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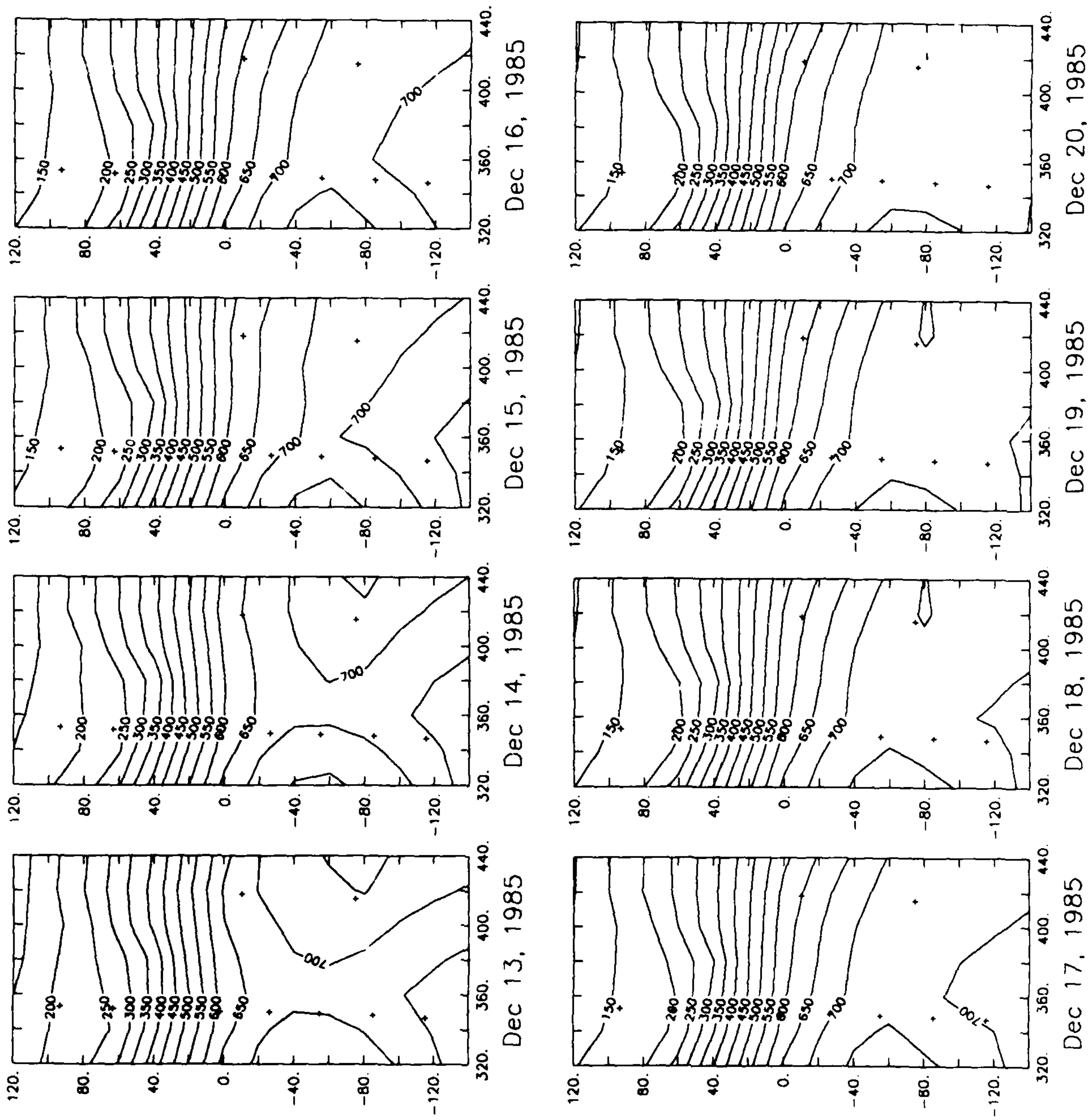
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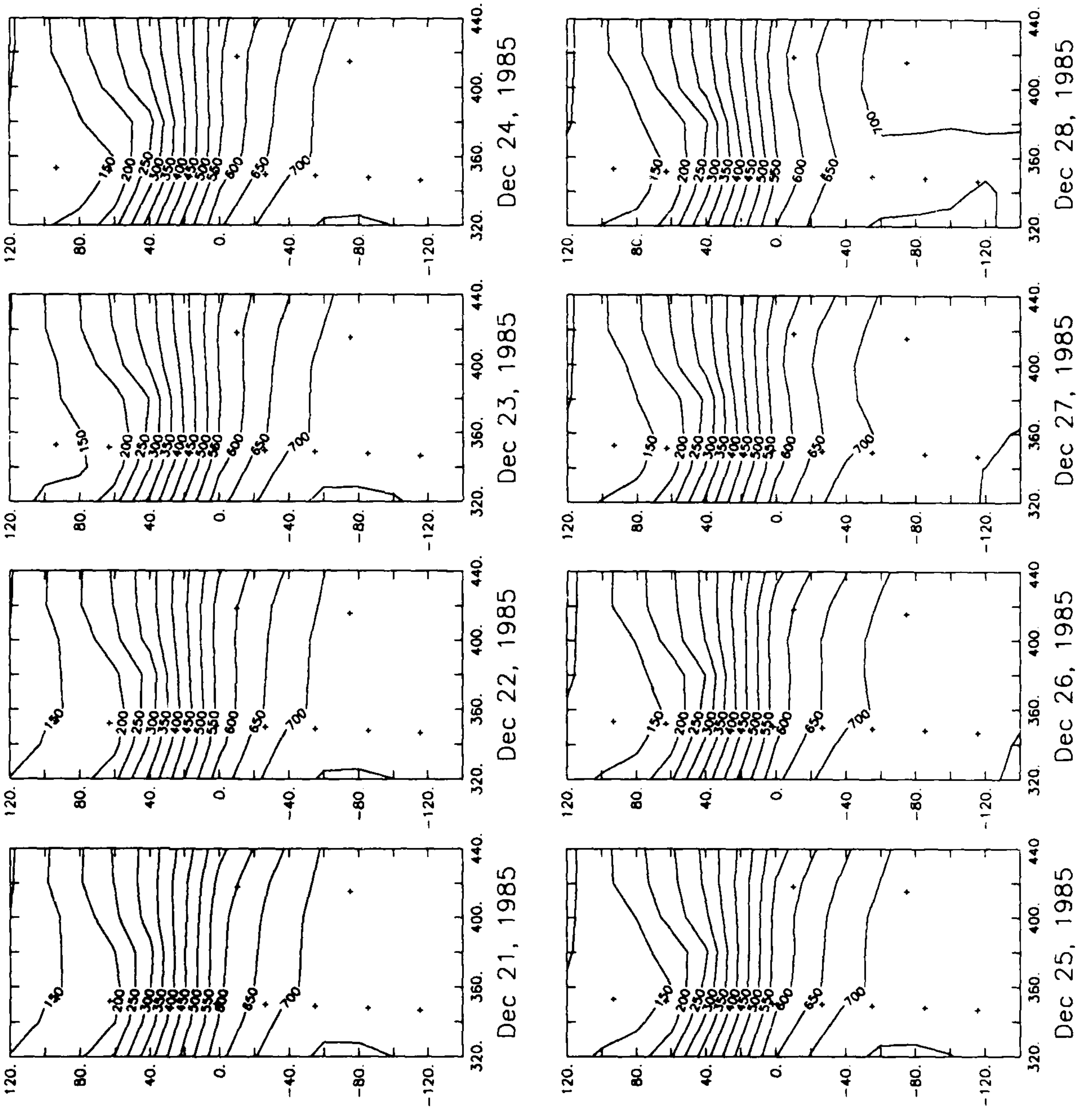
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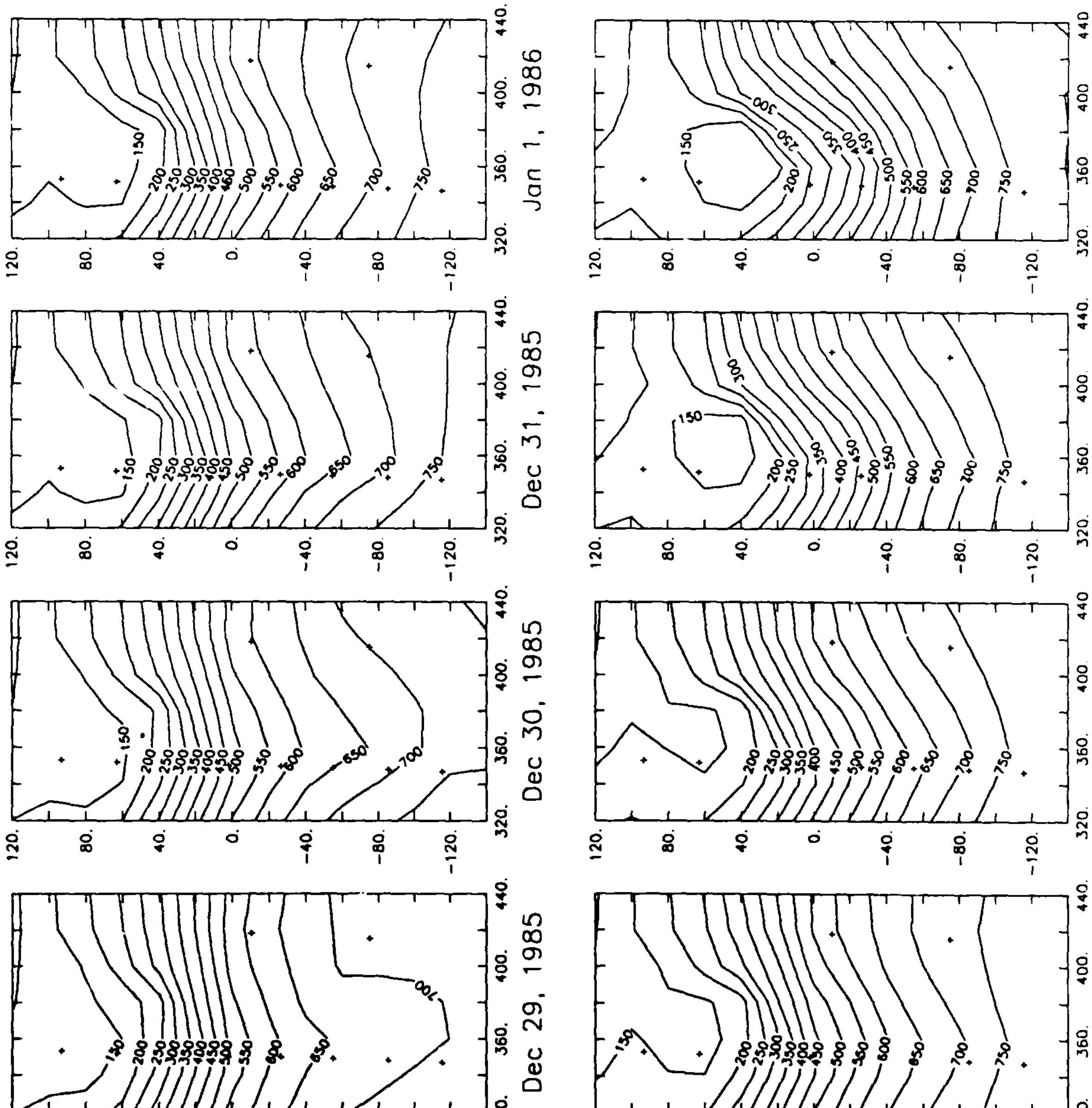
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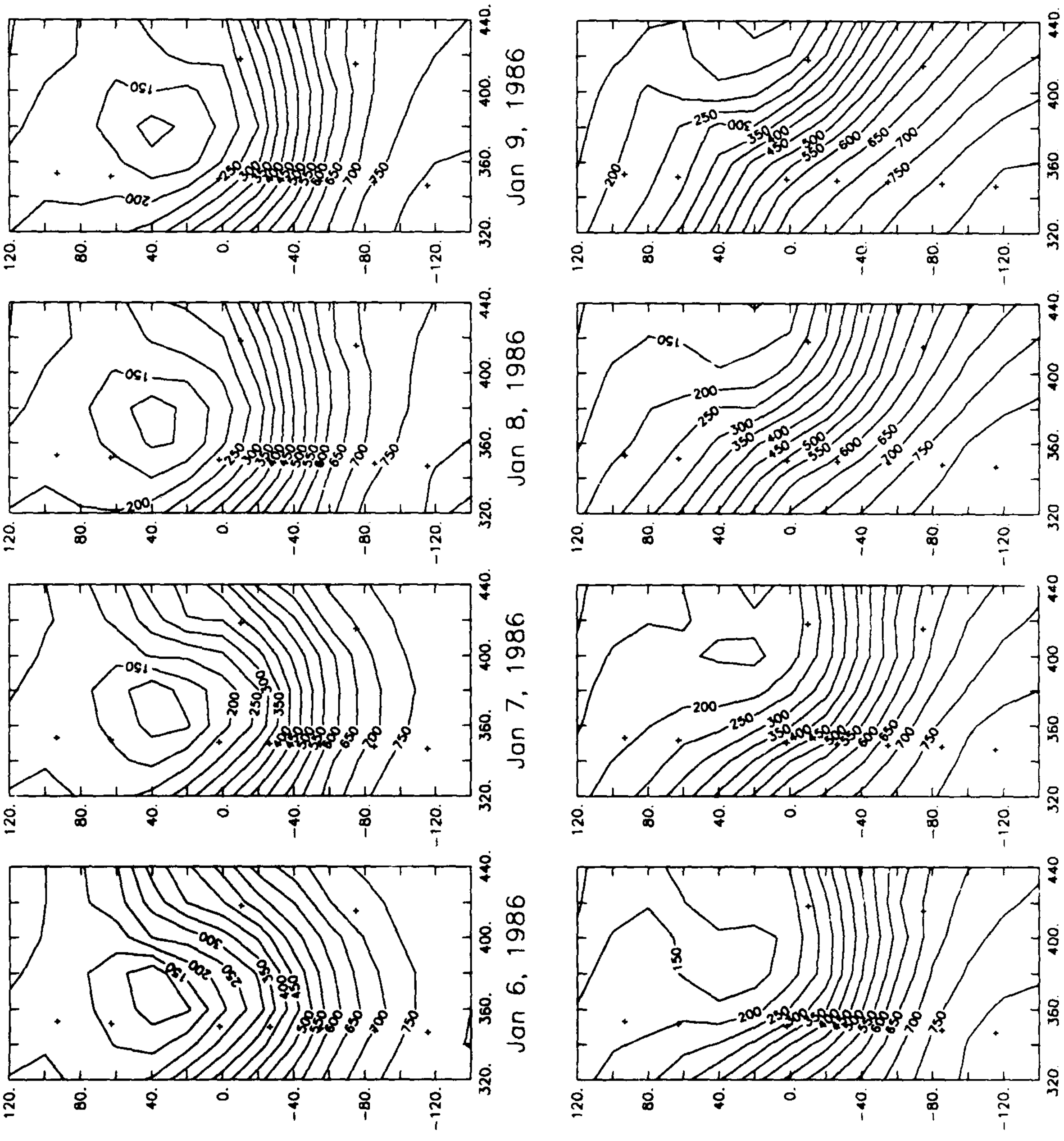
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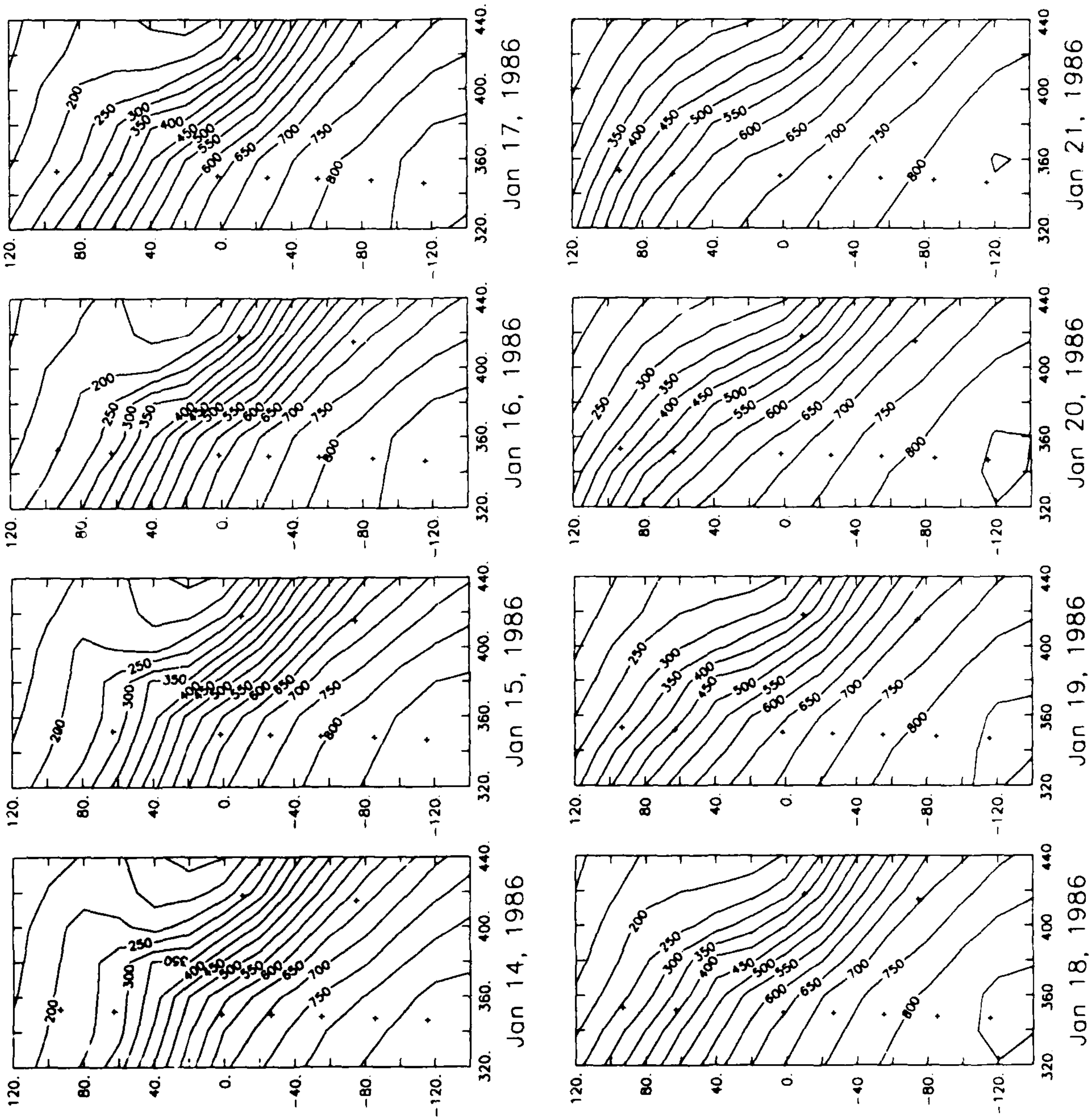
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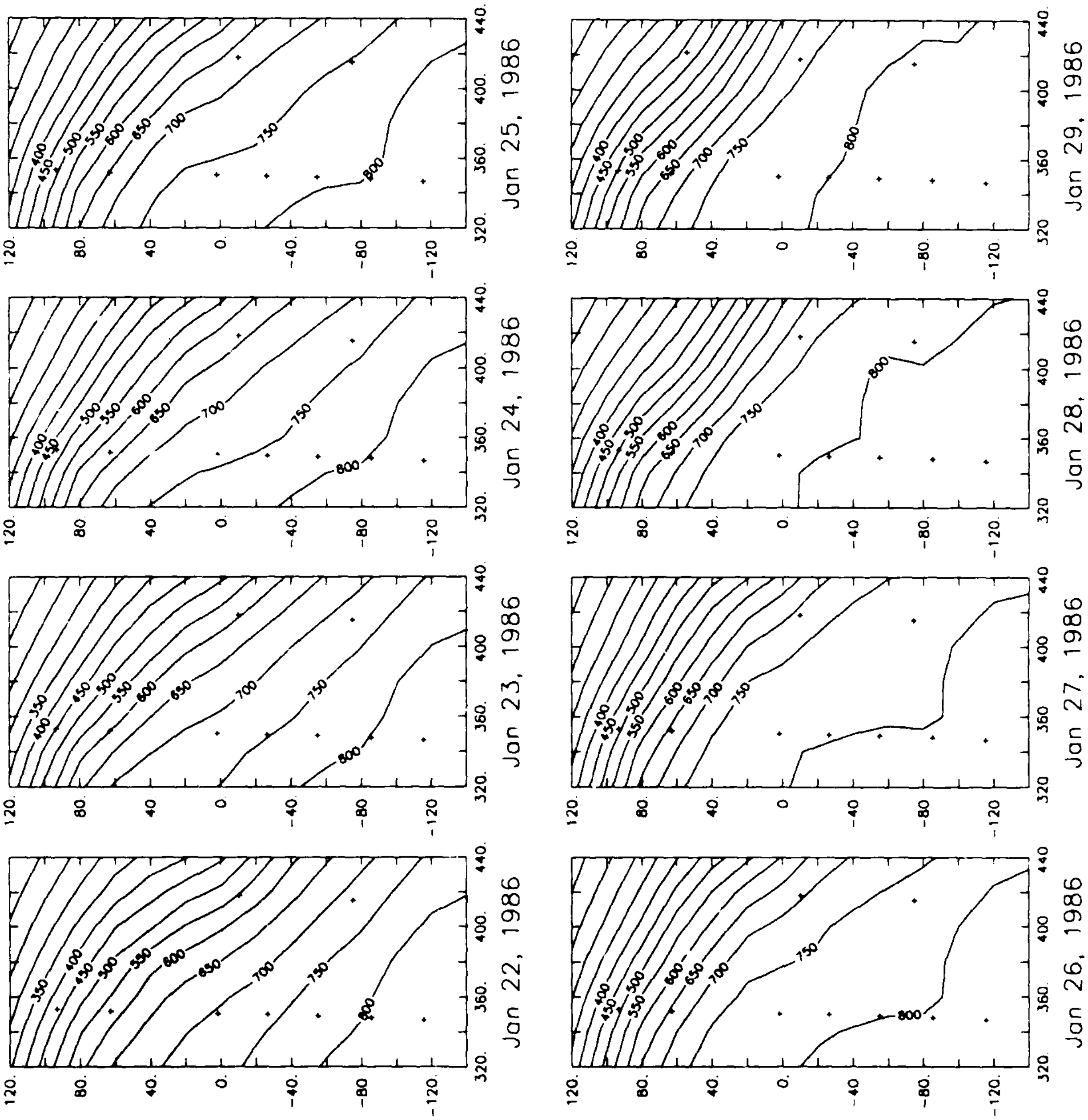
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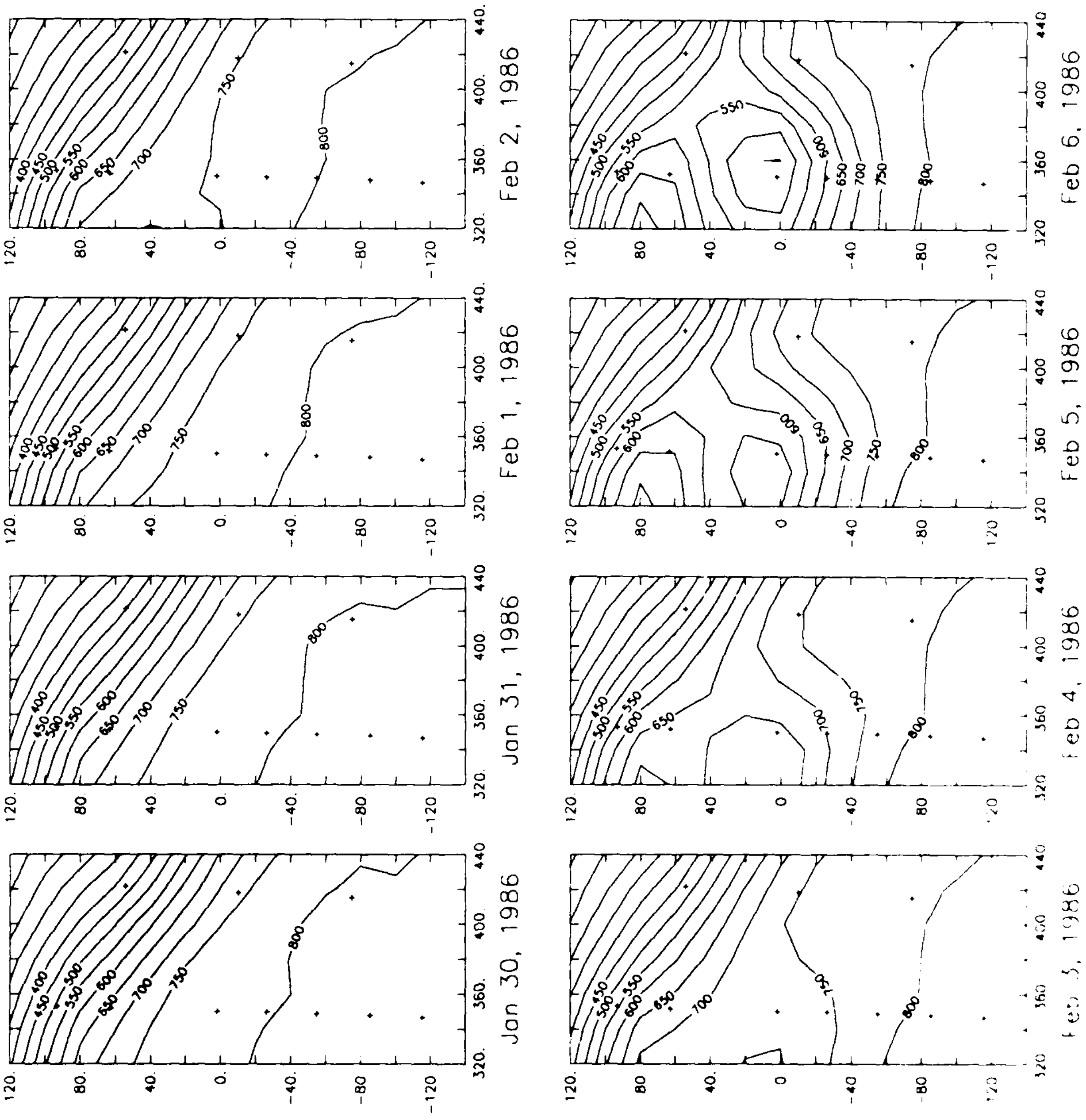
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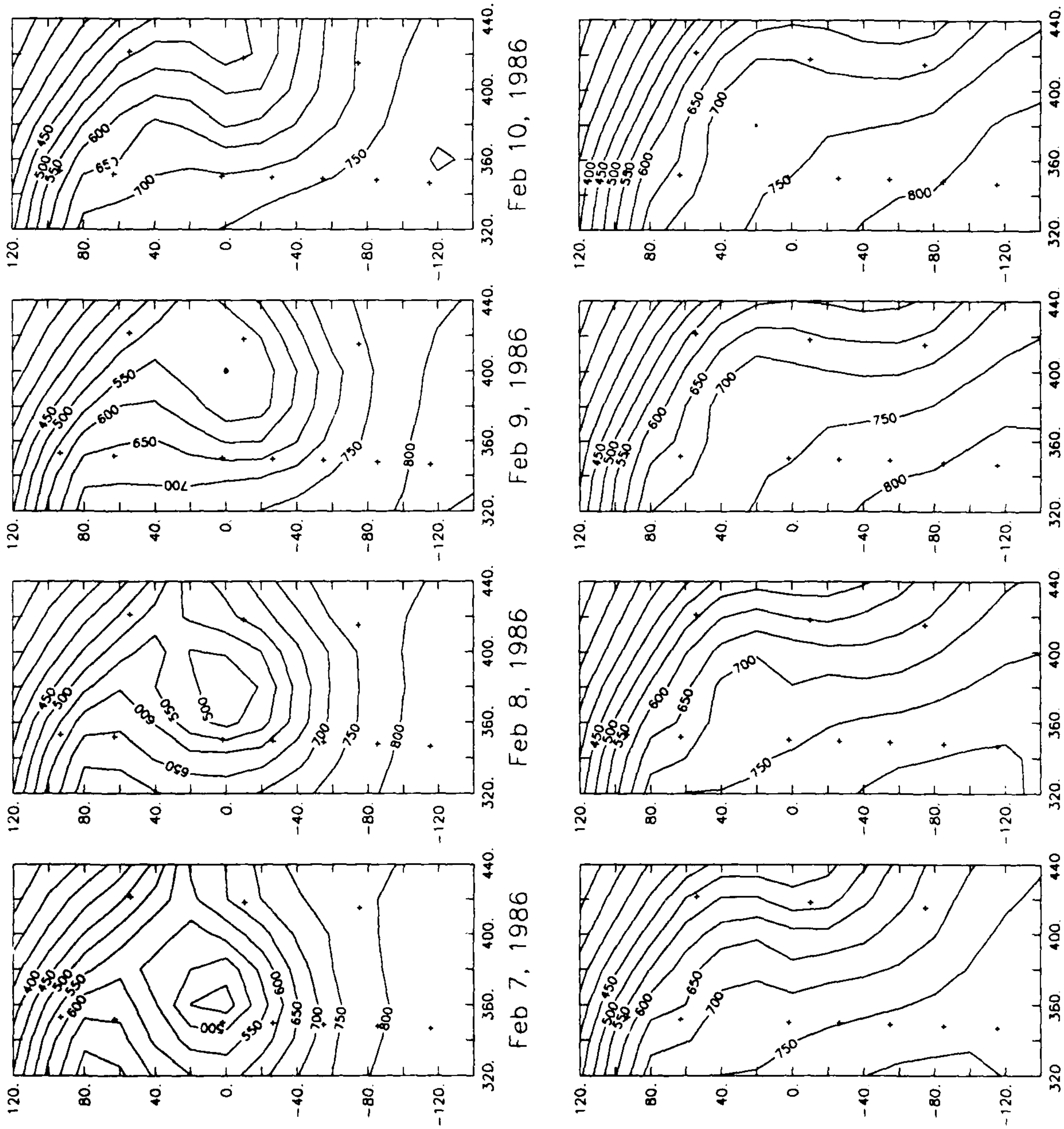
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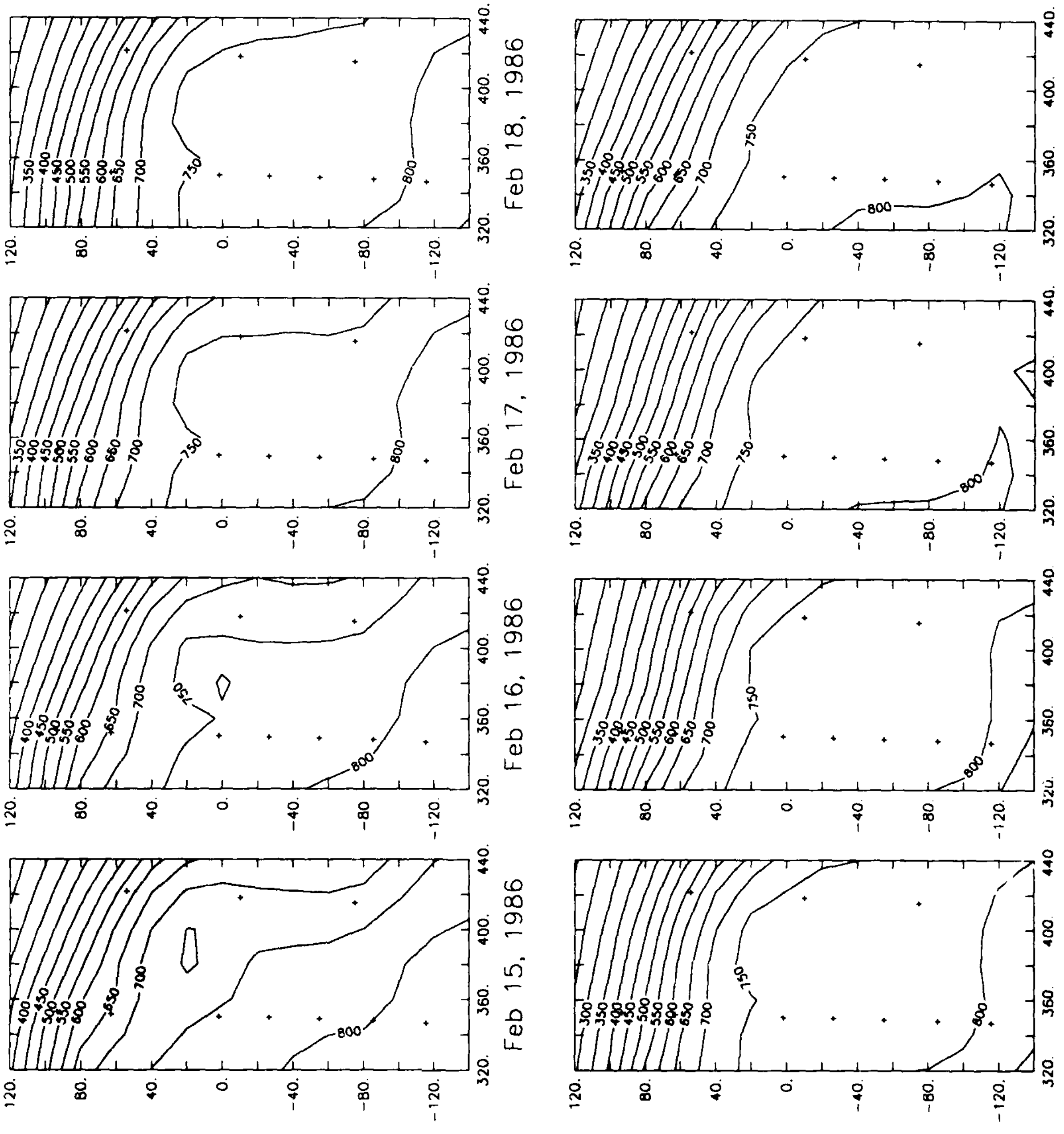
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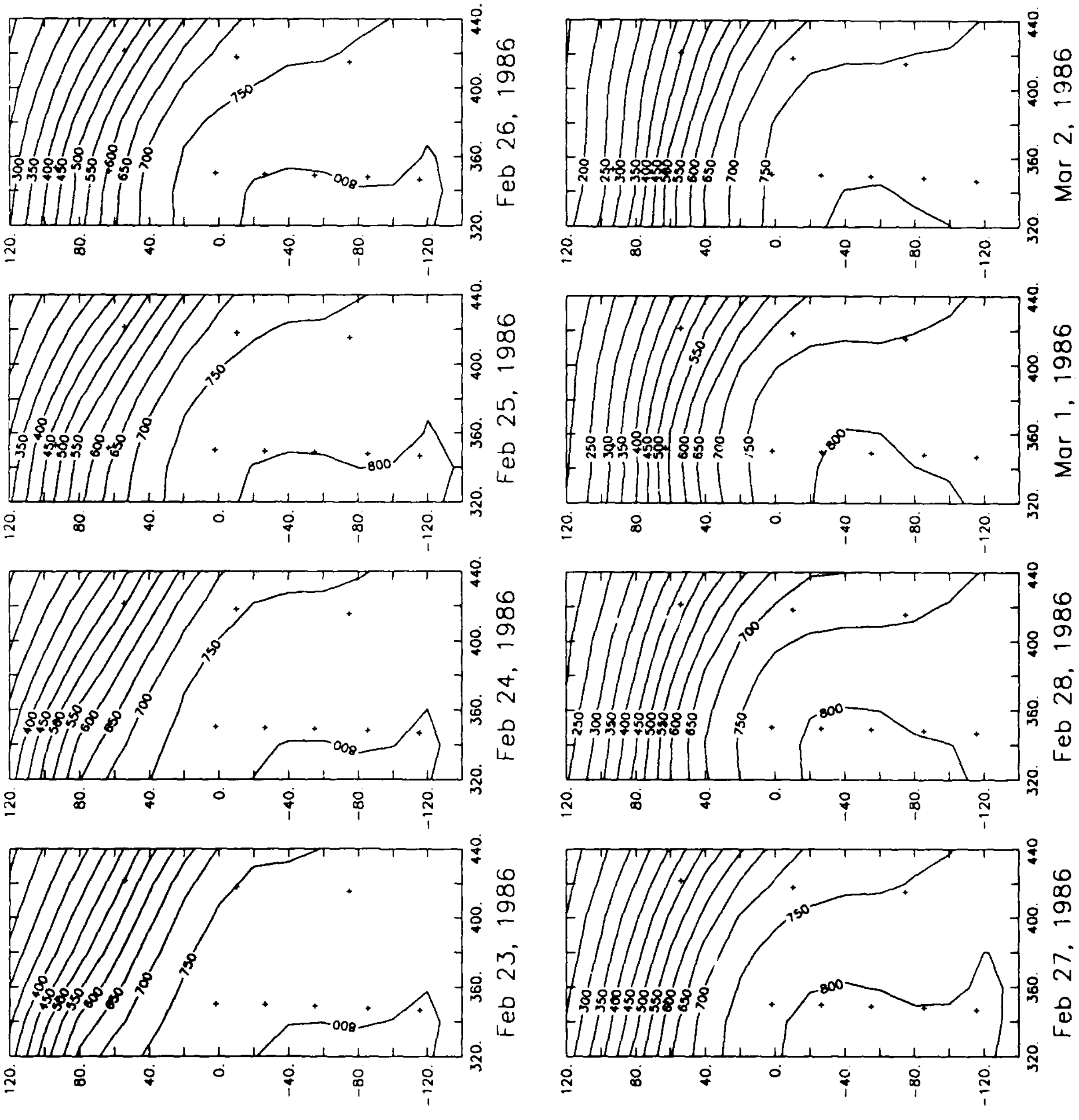
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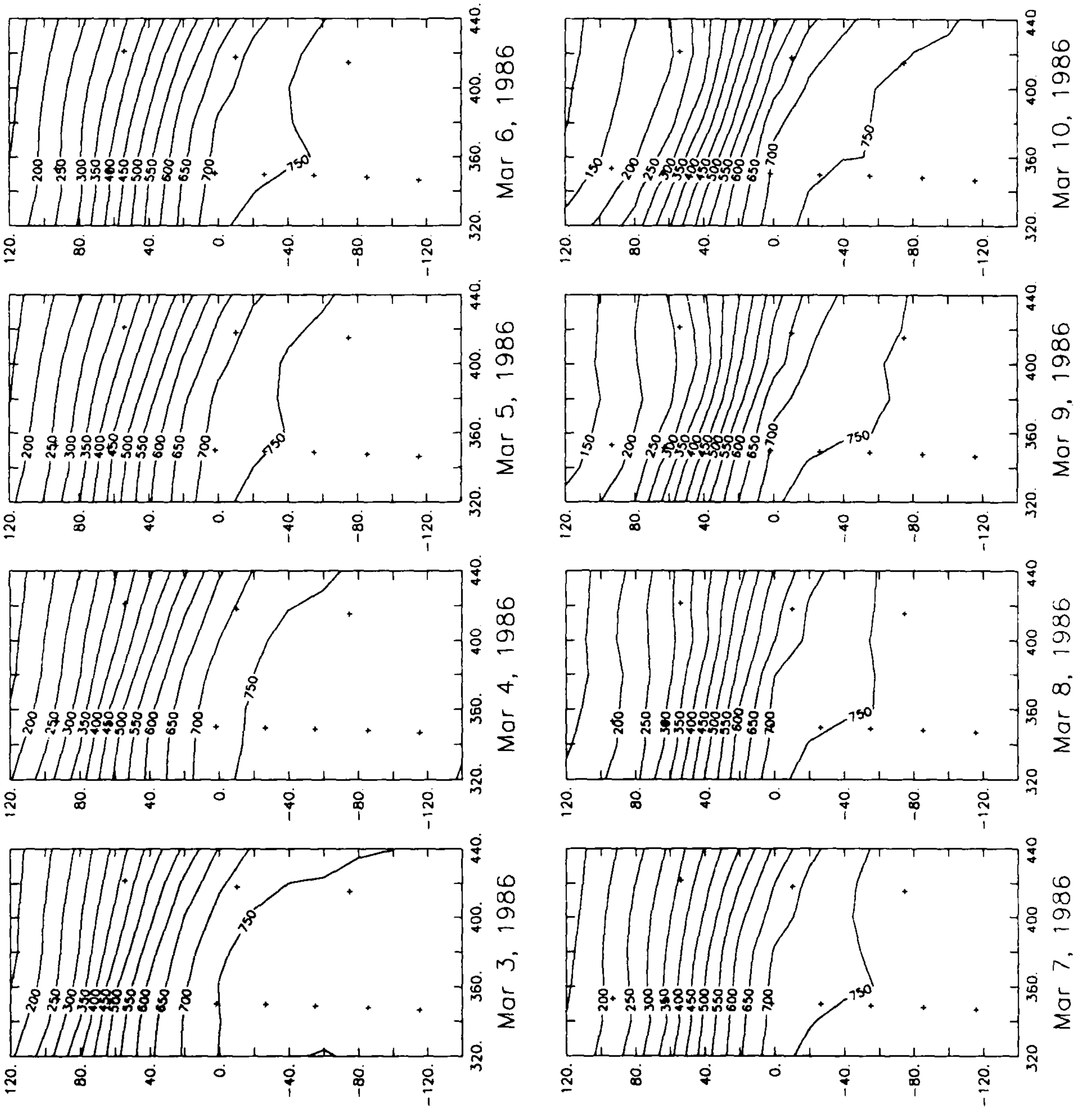
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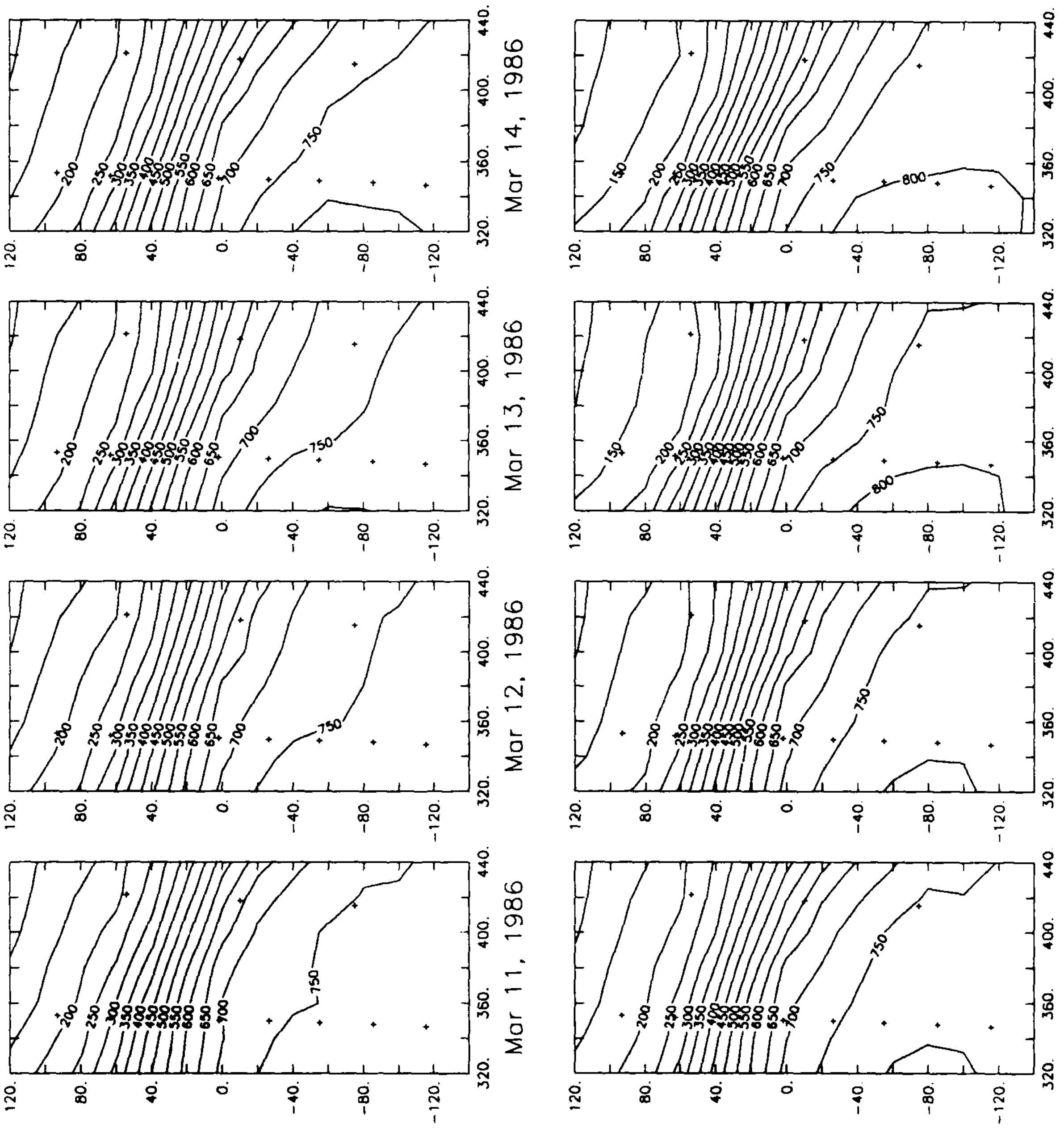
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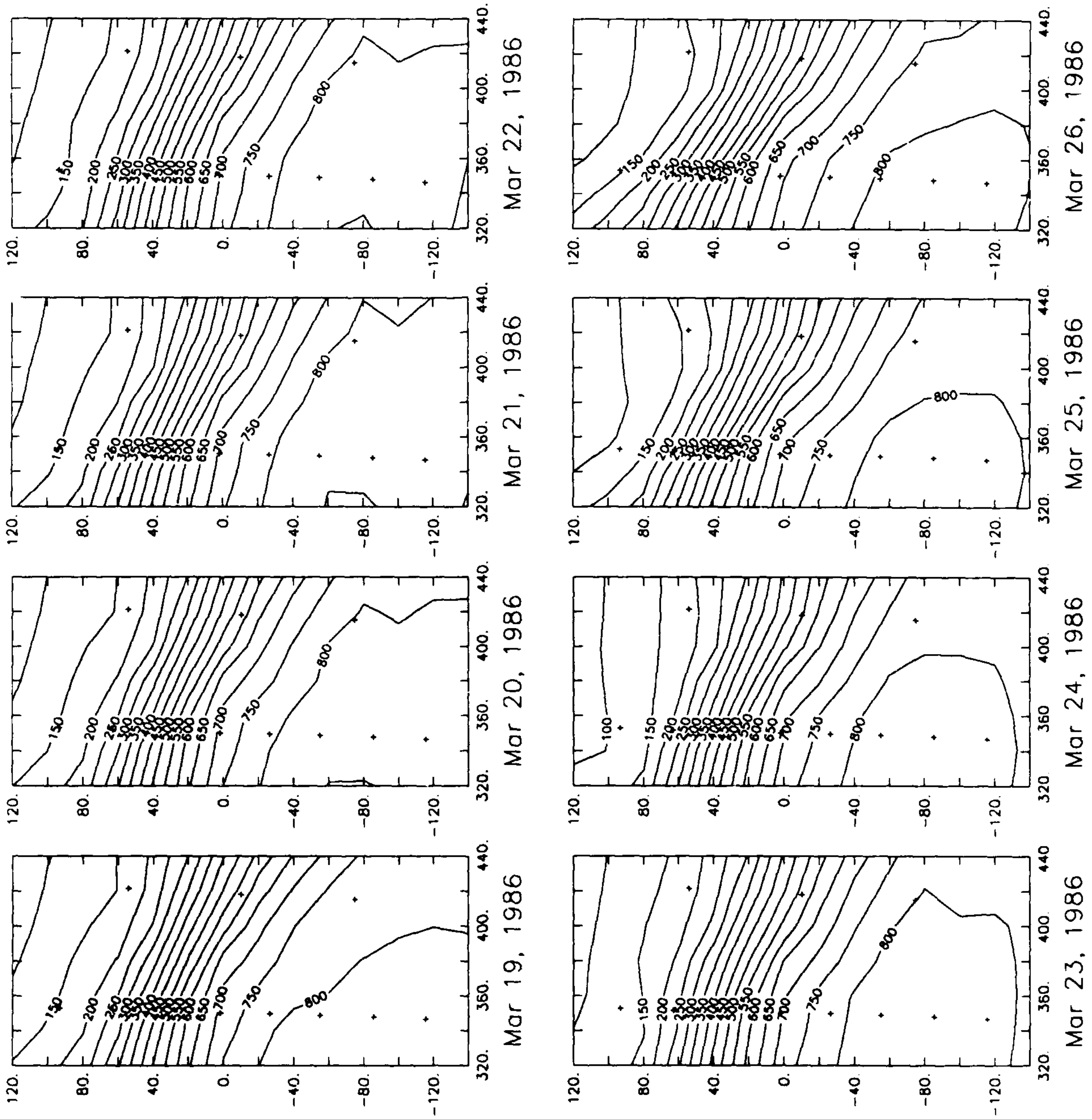
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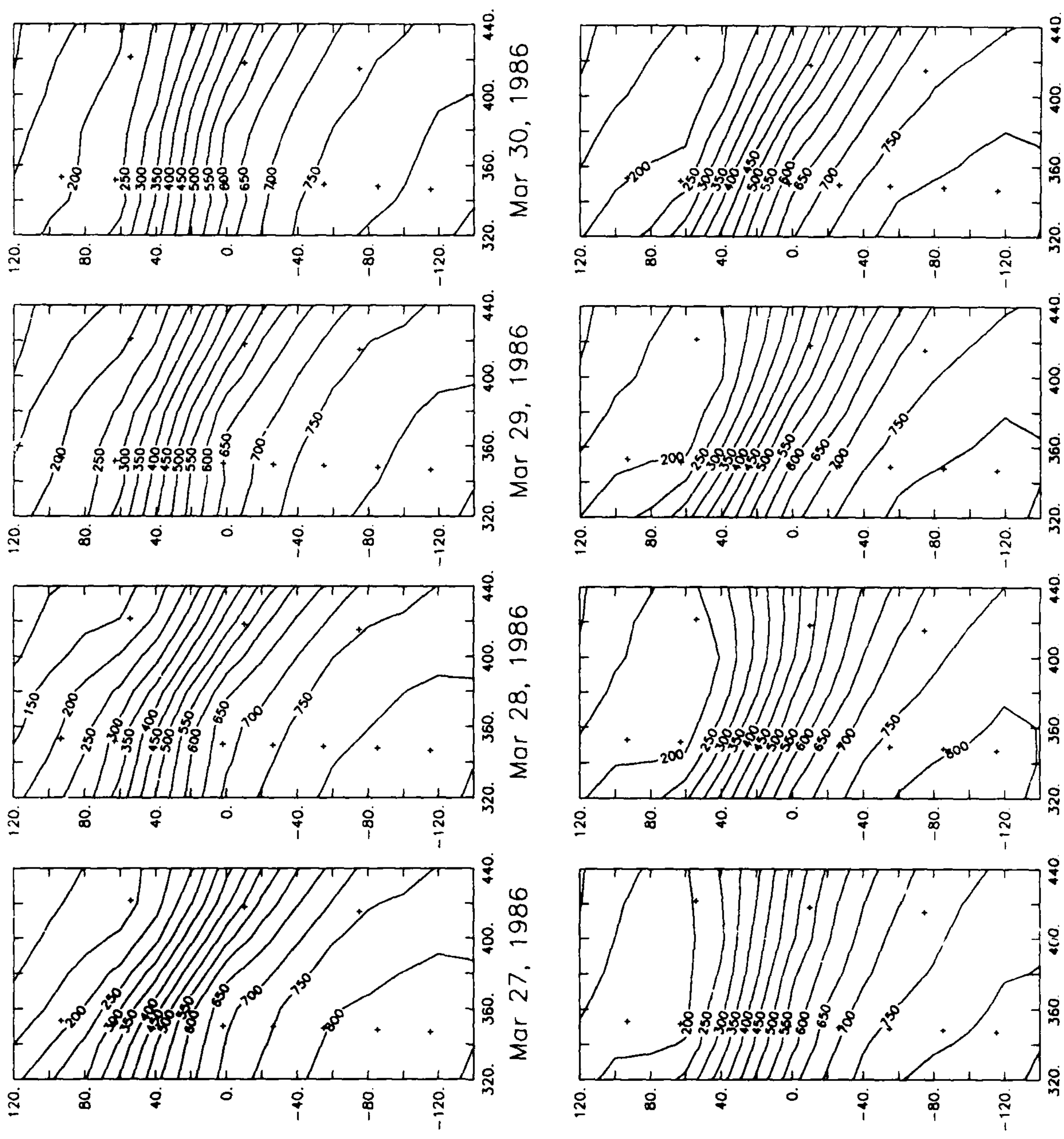

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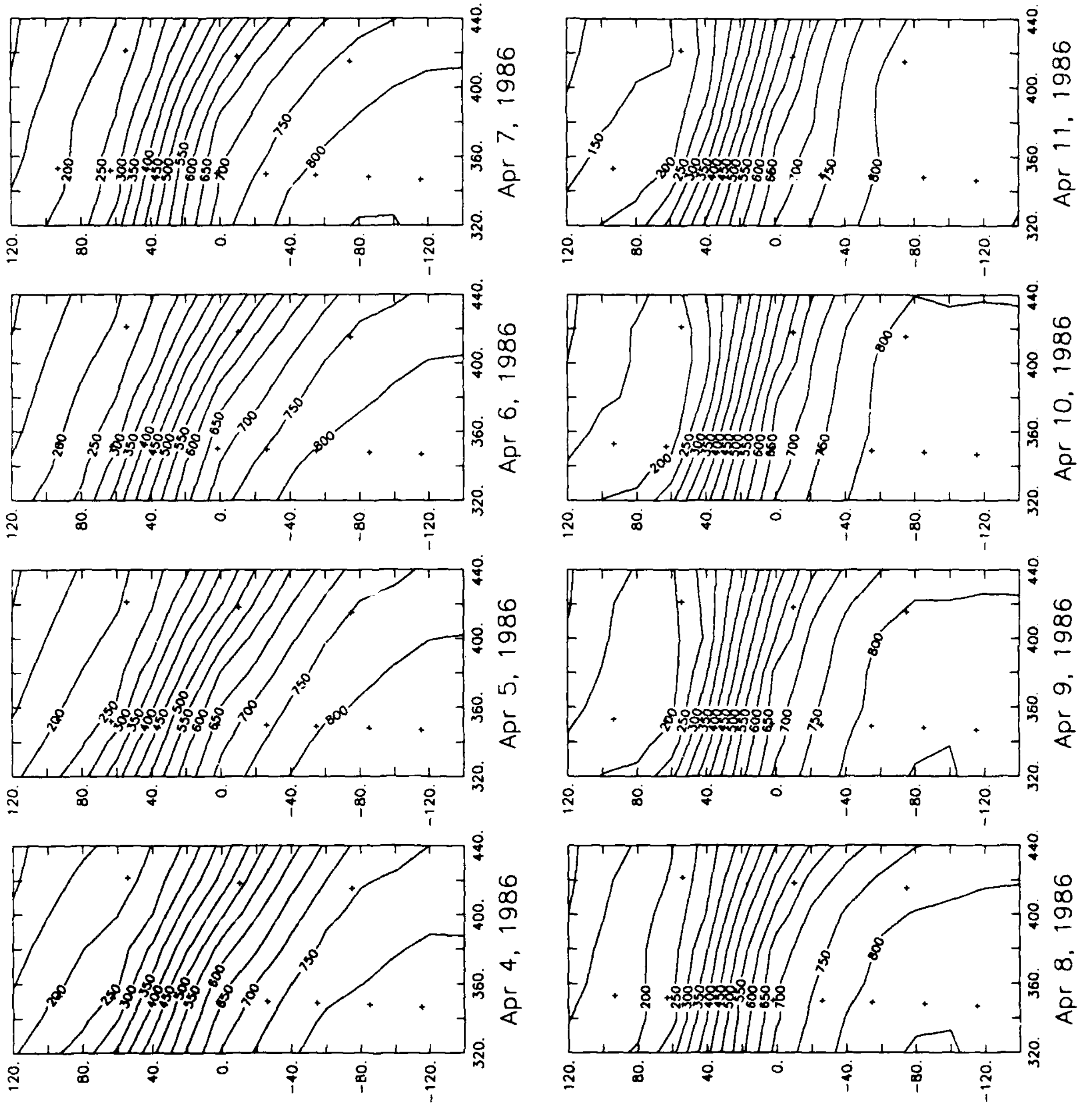
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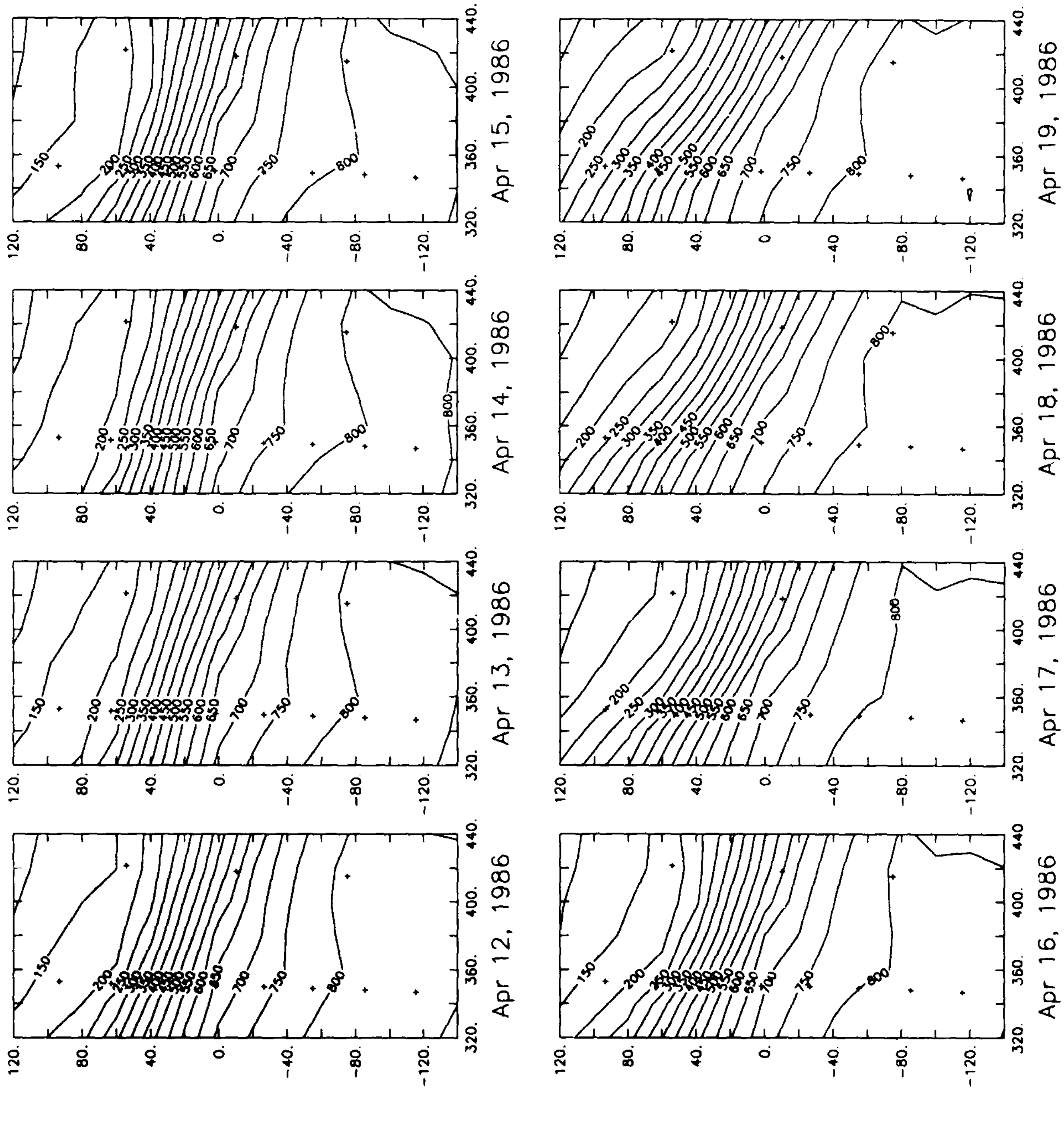
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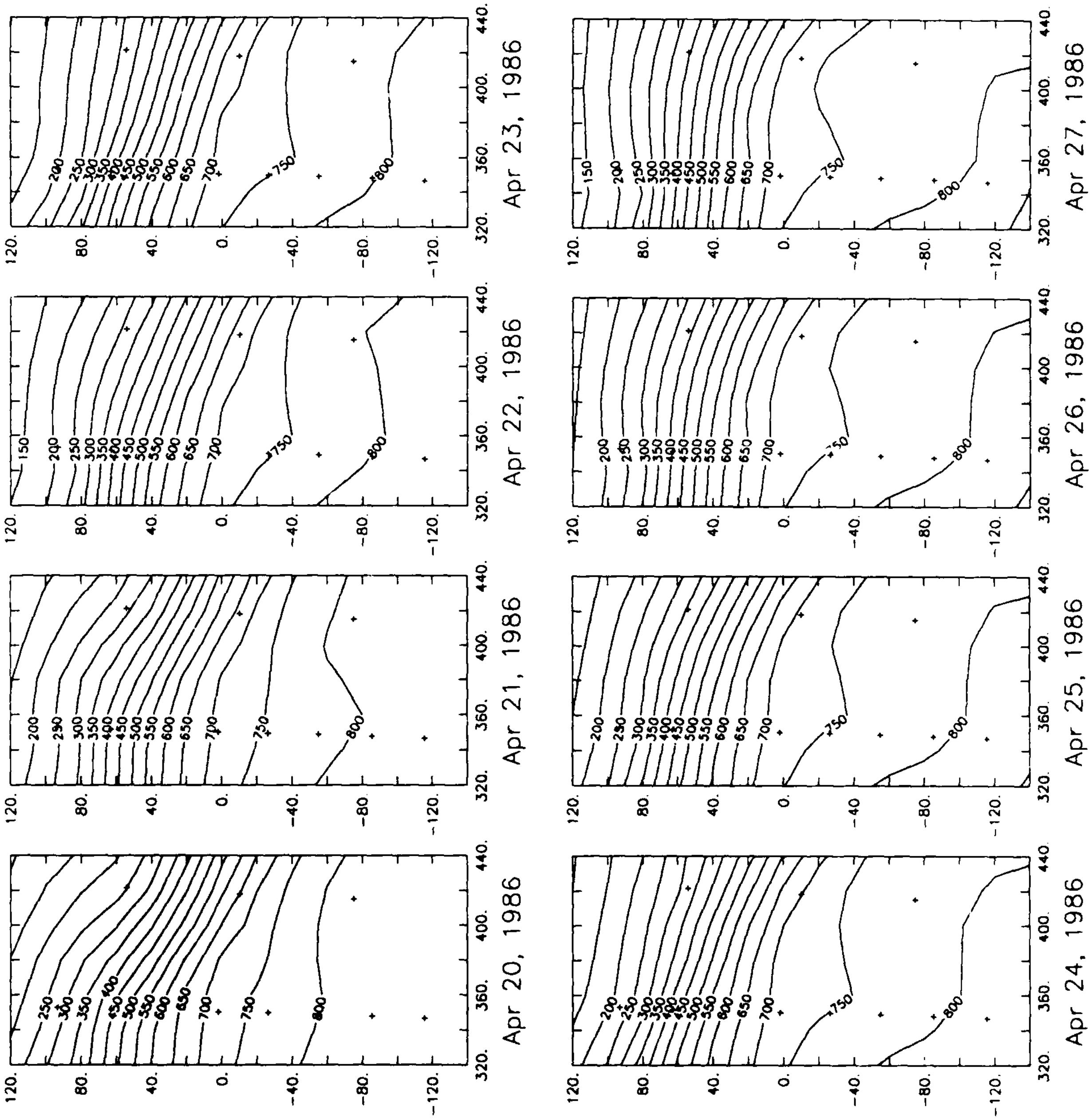
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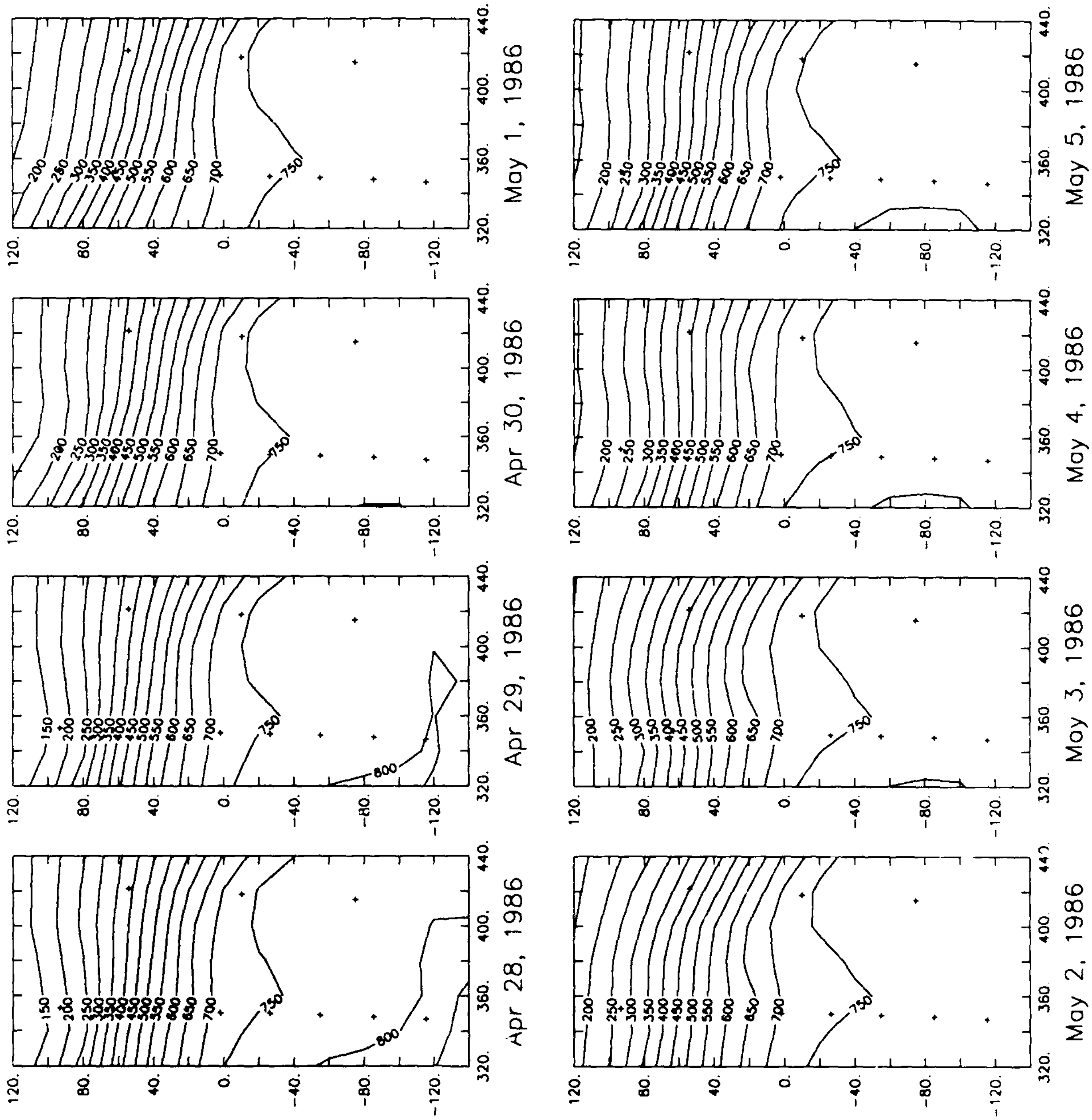
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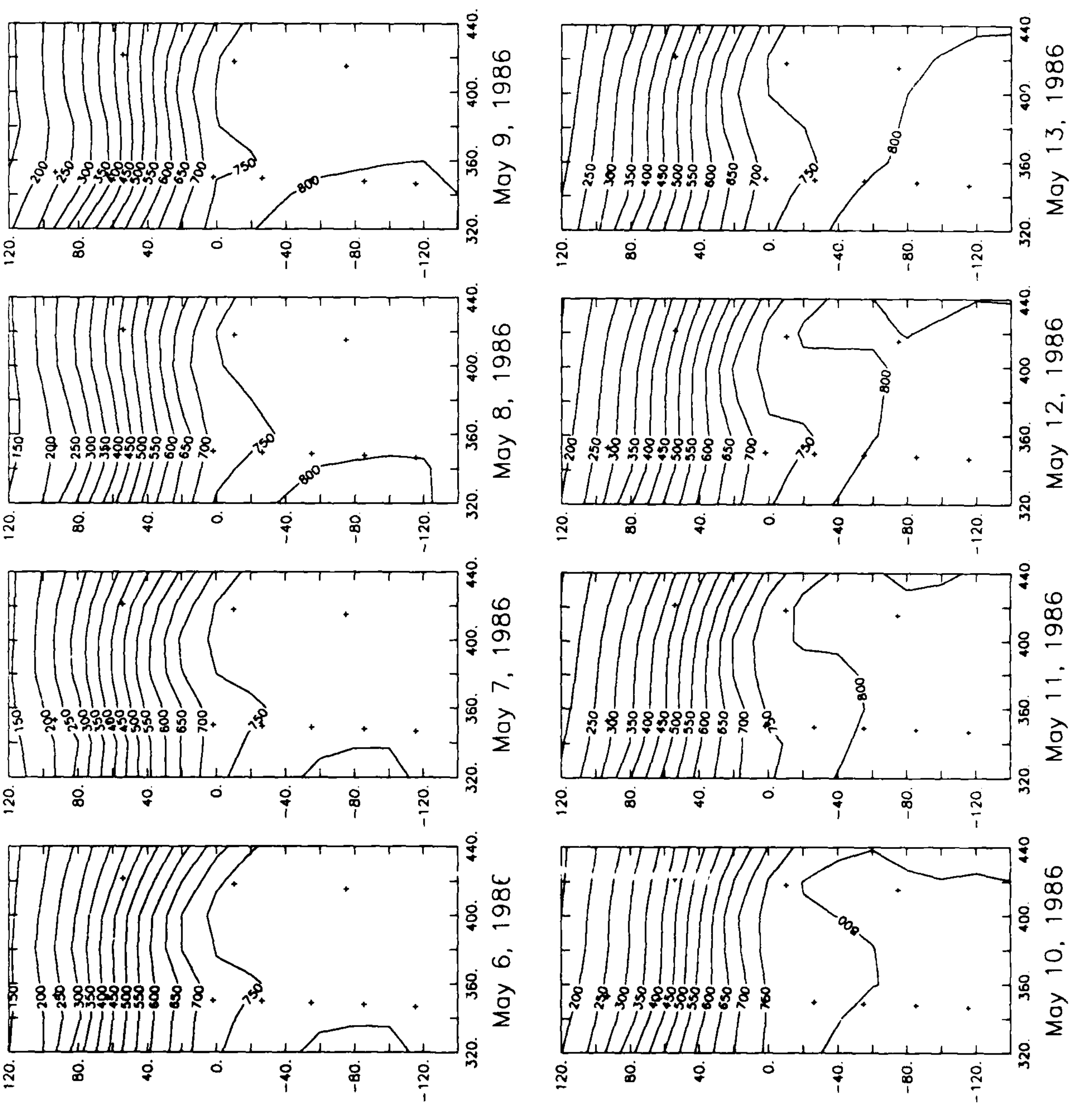
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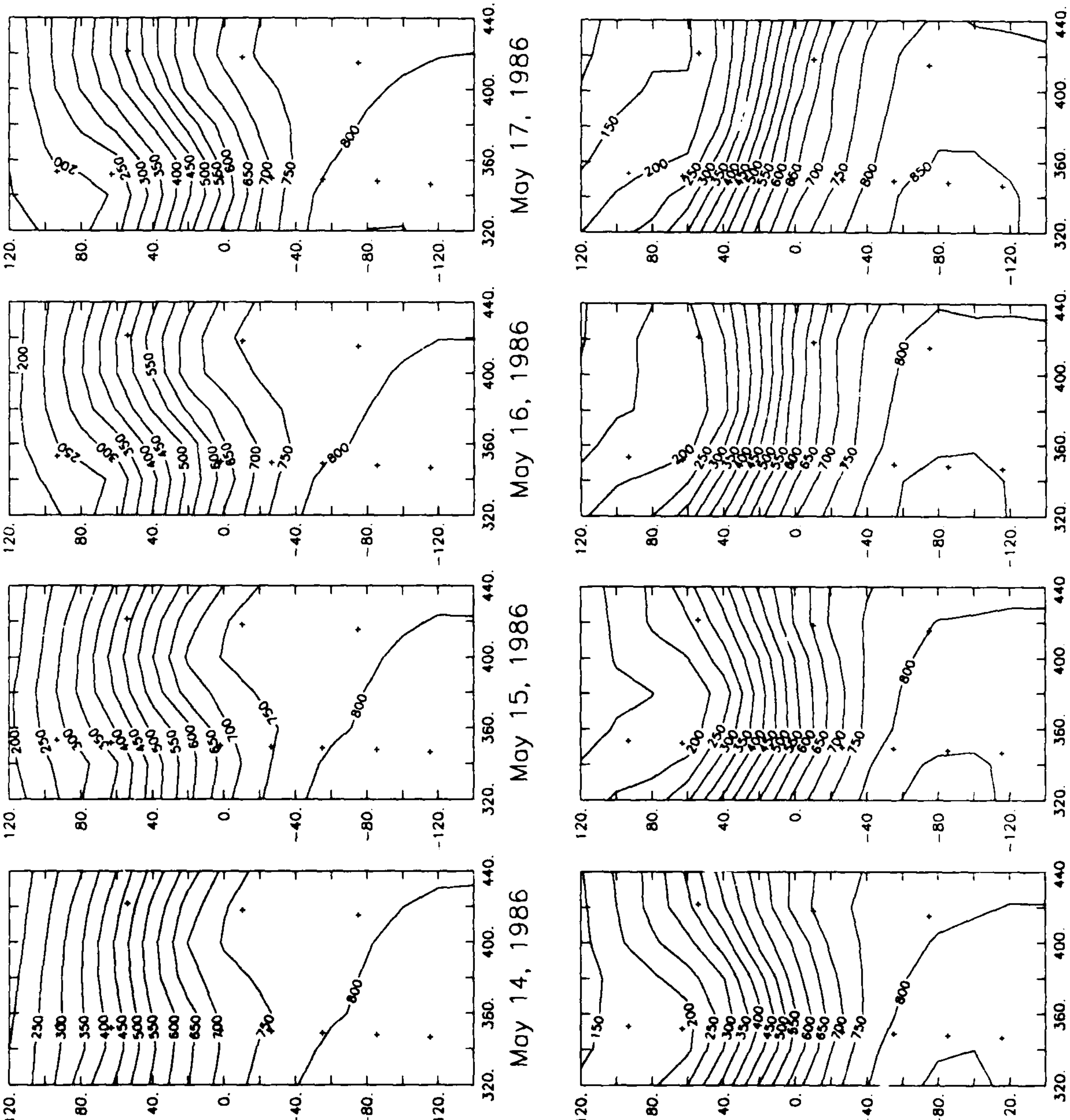

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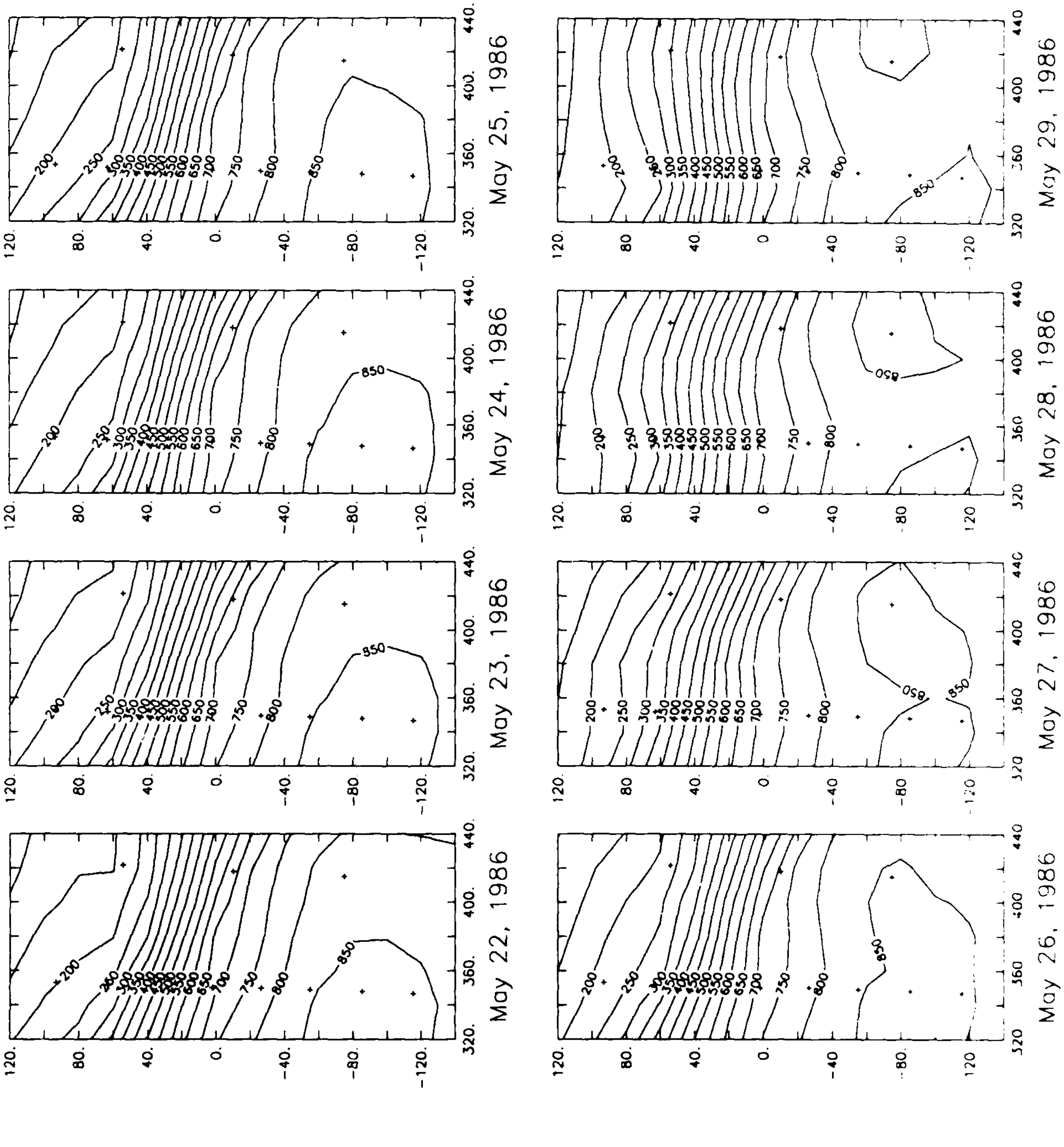
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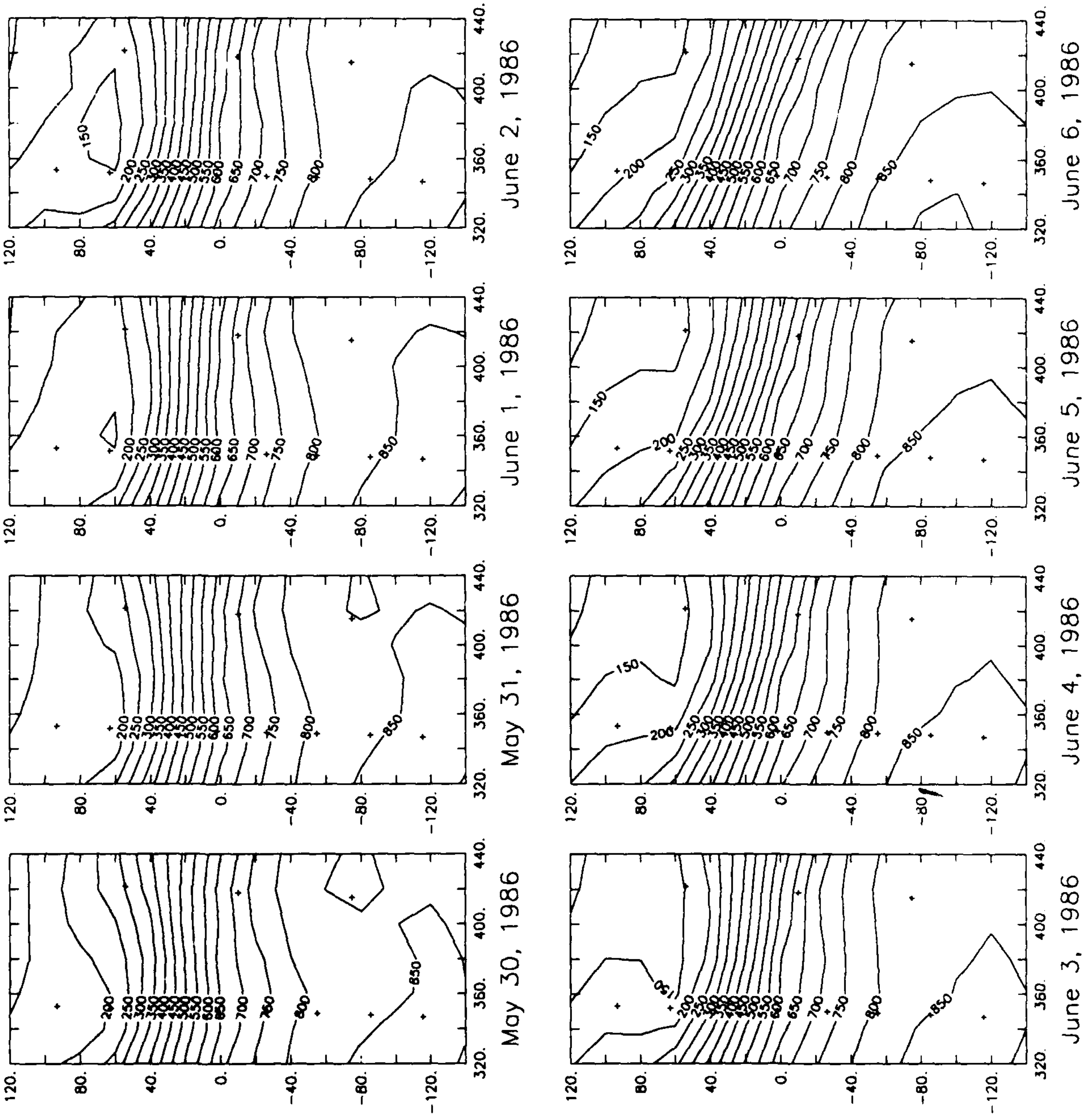
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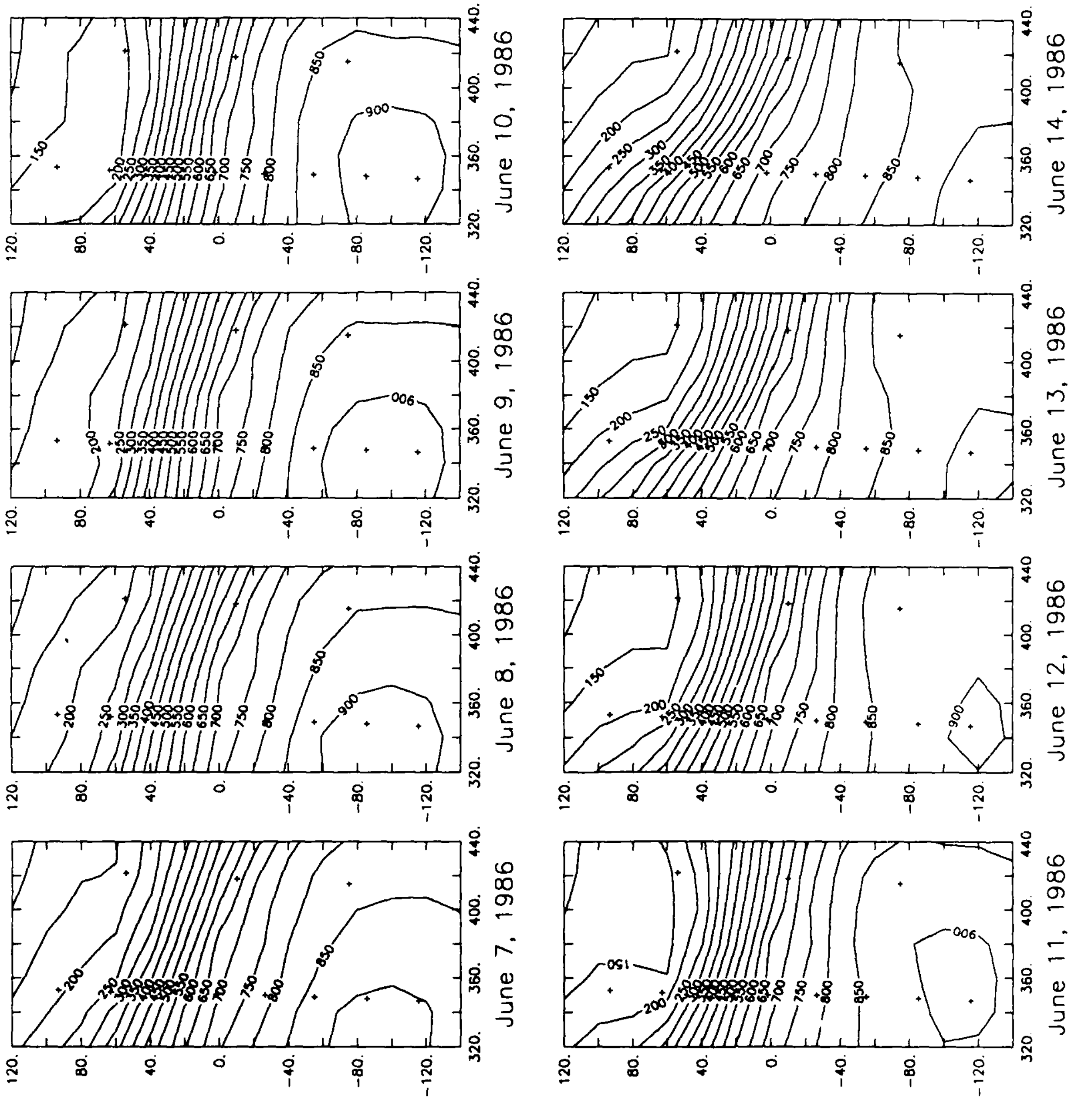
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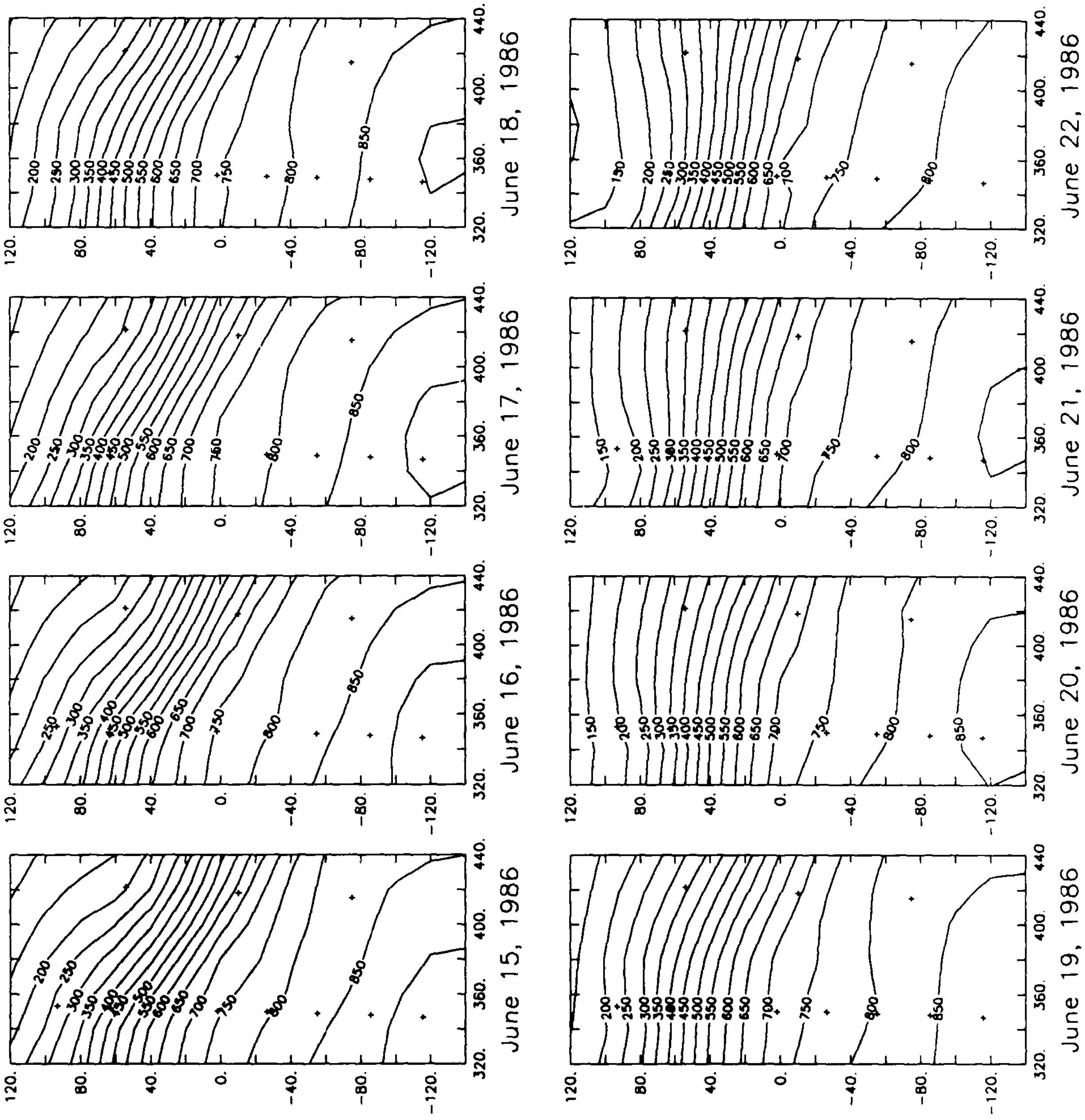
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The continuation of the Gulf Stream Dynamics Experiment was conducted at 70 deg W, about 450 km northeast of Cape Hatteras, to study the baroclinic transport and cross-stream thermocline structure of the Gulf Stream. This report documents the inverted echo sounder data collected during the May 1985 to June 1986 deployment period. Time series plots of the half-hourly travel time and low-pass filtered thermocline depth measurements are presented for ten instruments. Bottom pressure and temperature, measured at three sites, are also plotted. Basic statistics are given for all the data records shown. Maps of the thermocline depth field in a 120 km box region are presented at daily intervals.

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